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An International Journal

Official Organ of
The American Phytopathological Society

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Official Organ of The American Phytopathological Society

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PHYTOPATHOLOGY

VOLUME 22 MAY, 1932 NUMBER 5

SOME PATHOLOGICAL STUDIES ON APPLE CANKERS

NELLIE A. BROWN[1]

INTRODUCTION

The perennial canker of apple trees was a well-known disease when the writer began to study a phase of it. It has the appearance of a very infectious type of disease, for the cankers spread deep in and along the stems and may be so numerous and large that a third of the tree is involved (Fig. 1, A and B). It is known only in the Pacific Northwest and such varieties as Yellow Newtown, Ortley, Jonathan, Esopus Spitzenburg, and Winter Banana are susceptible to it; the Northern Spy, Winesap, and Delicious are, in general, not considered susceptible. In spite of the fact that fruit from diseased trees has been shipped elsewhere, the disease has not been spread to the East. The cultivated apple and very rarely the pear are the only hosts known.

In 1925 Zeller and Childs (11) showed that what was thought to be anthracnose, produced by the fungus *Neofabreae malicorticis* Cord., was really 2 canker diseases instead of 1. They gave the name perennial canker to the second type, pointed out the differences between the 2 cankers, and described an organism producing perennial canker and named it *Gloeosporium perennans*. It is not within the scope of this paper to deal with what is considered the anthracnose type. It is sufficient to state that in these investigations if the sori on a canker had distinctly hooked spores, the distinguishing feature of anthracnose, instead of the curved spores of perennial canker, the data obtained in connection with it are not included in this paper. If there were no fruiting bodies on the canker, rarely any difference could be detected by the writer between anthracnose and perennial canker and, so, the canker was classed as the latter. When perennial canker was first described it was thought the organism remained in the tissue and continued to infect it, producing the new canker growth from year to year. Now it is thought by some workers that the callus tissue around the old canker has to be reinfected every year, therefore it is really an annual disease instead of a perennial, and to produce the canker advance or new cankers elsewhere on the tree there must be some other agent or condition to help bring it about.

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FIG. 1. Young and old stages of apple canker, Hood River Valley, Ore. ×⅓. A. Canker on stem of Ortley apple. Three sets of isolation plates were made from this canker in December, 1928. No Gloeosporium colonies appeared in 2 of the sets; but 4 *Gloeosporium perennans*, 2 Penicillium, 24 white bacterial (all same species), and 19 yellow bacterial colonies (all same species), appeared in the third set. B. Advanced stage of canker on Yellow Newtown stem of apple.

In the winter of 1928–29 when the present work was undertaken, plant pathologists believed perennial canker to be a true parasitic disease because it has all the appearances of a disease induced by an active parasite. Entomologists who studied the cankers believed that the woolly apple aphis was the primary cause of the disease and that the fungus usually followed severe aphis infestation. Both groups of workers had evidence to back up their claims and consequently there was confusion as to methods for prevention or control of the disease. Papers dealing with the evidence to support their views were published by Childs (1, 2), Cooley (3, 4), Fisher (7, 8), Miller (3), McLarty (10), Reeves (7, 8), and Shear (4).

In 1930 Cooley and Miller (3) reported "that the margins of healthy calluses may be injured by cold and that canker infection readily takes place in the winter-injured margins of pruning wound calusses." Winter injury as the primary cause of perennial canker was brought out further by Cooley and Shear in 1931 (4).

The same year (1930) entomologists and plant pathologists of British Columbia concluded that perennial canker is found principally in districts where the woolly aphis is prevalent and in varieties subject to winter killing. Güssow (9) states: "Cankers may be more or less numerous depending upon the resistance of varieties to winter injury and when and where unusually prevalent this condition can almost without exception be traced to susceptibility to winter injury as well as to the presence of woolly aphis." He considers the aphis to be the carrier of *Gloeosporium perennans*.

PURPOSE OF THIS INVESTIGATION

The work reported in this paper was undertaken with a view to making a study of the location and extent of the fungus *Gloeosporium perennans* in the tissue of the apple cankers and the rapidity with which it spread in apple stems. Material was sent to Washington, D. C., from the Hood River Valley, Oregon, and the first part of the work was done in Washington. Isolations were made from many cankers of various sizes and ages and from different parts of the cankers in order to recover *G. perennans* from various parts of cankered areas. Part of this material was prepared for sectioning to study the presence and extent of the fungus in stained tissues.

VARIOUS ORGANISMS FOUND IN CANKERS

Repeated isolations from the inner bark and wood of cankers brought out the significant fact that had not been suspected—that *Gloeosporium perennans* was not always present in the canker tissues and that some other fungus, such as Alternaria, Fusarium, Cladosporium, or Dematium, was frequently present instead. The Dematium had a bacteria-like-colony growth and seldom developed any mycelium in plate cultures. Often pure cultures of a white bacterium occurred on the isolation plates, and sometimes there would be a mixture of more than one fungus or of a fungus and the white bacterium. The media used for the isolation plates included potato-dextrose agar. Corn meal, malt, Dox, apple, and beef agars also were used. Potato-dextrose agar, however, was found to be the most satisfactory. Using fall and winter material, the white-bacterium and Dematium colonies were the most abundant on the isolation plates whether alone or with some fungus. Fungi other than Gloeosporium occurred in the plates so frequently that they could not be considered chance invaders. The white bacterium frequently threw a yellow sport. The isolations were made

before the sections were stained, and were studied to be certain that the cankers under investigation contained the fungus *G. perennans* and that all data relating to the position and extent of this fungus in the tissues, when studied in sections, could be referred to as *G. perennans*.

The continued appearance of bacteria and the various fungi on isolation plates and the frequent absence of *Gloeosporium perennans* made necessary a change in the work that had been planned. While it was still of value to study the location and extent of an invading organism in the diseased apple stems, the presence of so many different organisms made it necessary to make many isolations from cankers collected in various localities. This procedure prevented drawing a conclusion from results obtained in any one locality. Up to this time there had been no definite question among plant pathologists interested in the problem regarding the pathogenicity of *G. perennans* as the cause of perennial canker of apple trees.

INOCULATIONS WITH GLOEOSPORIUM PERENNANS IN ORDER TO PRODUCE YOUNG CANKER TISSUE FOR STUDY

In order to study the apple-stem tissues during the first stages of canker infection, inoculations were made into young apple trees. Seedlings 1 to 2 years old from Jonathan seeds, growing in pots in the greenhouse in Washington, D. C., were inoculated with pure cultures of *Gloeosporium perennans* by means of needle pricks in February and March, 1929. The trees were kept at various temperatures on the benches and in moist chambers, but no disease could be induced. Inoculations were also made with spores taken from mature sori on cankers. Thirty-three seedlings were inoculated with pure cultures and 13 with spores taken from sori on cankers. The seedlings were under observation for over 2 months. These results were negative also.

If *Gloeosporium perennans* were a true parasite and active in producing perennial canker in the Pacific Northwest, it would seem that it could scarcely fail to produce some infection in the East under these various conditions. The fact that it did not produce infection together with its infrequent occurrence on plates poured from the interior of cankers, led the writer to think that something else must feature in the production of the disease.

ISOLATIONS IN WASHINGTON, D. C., FROM CANKERS SENT FROM HOOD RIVER, OREGON

In December, 1928, and in January and February, 1929, platings were made from old apple-canker tissue carrying into the plates pieces of the material that had been first washed in water, dipped in alcohol, then in mercuric chloride 1–1,000 from 15 to 60 seconds, washed again in sterile

water, and cut up in a tube of sterile water. Sori containing spores of *Gloeosporium perennans* were usually noted on the surface of the cankers.

From 17 sets of isolations comprising 136 plates no uniformity of isolation of *Gloeosporium perennans* resulted. Potato-dextrose and Dox agar and occasionally corn-meal agar or beef agar were used as media for the isolations. In 9 of the 17 sets, no *G. perennans* appeared on the plates. Various organisms, both fungi and bacteria, appeared, of which the white bacterium and Alternaria were the most abundant. The other fungi were Dematium and Fusarium.

Isolations from the button type of canker. There is a type of canker prevalent in Washington State designated as the button stage. As the name indicates, the lesion is button-shape; it usually varies in size from 5 mm. to 2 mm. across. It was thought perhaps this was the beginning stage of the disease and, if so, *Gloeosporium perennans* should be very abundant in it, and the other organisms found in old cankers should not be present.

Seven sets of isolations, including 83 plates, were poured from cankers of this type received from Wenatchee in March, 1929 (Fig. 2, B). There was no spring advance indicated in these lesions, and, as the tissue was somewhat dark, the lesions must have developed some months previous, possibly in the fall. The plates that were made with Dox agar, potato-dextrose, and beef agar were watched carefully and studied daily for 2 weeks.

The most abundant organism present was Dematium, numbering 224 colonies; the next most abundant was the white bacterium, of which there were 136 colonies. There were 38 colonies of *Gloeosporium perennans;* other types of bacterial colonies, 15; and other types of fungi, 11 colonies.

Several different organisms were usually isolated from each lesion; no canker produced a pure culture of any one organism.

These results did not substantiate the earlier idea of the writer that the button lesion was the initial stage of the disease. It seemed rather that the button stage was a case of arrested canker development in which the tree was able to overcome the disease because of favorable conditions. In these lesions, as in the large typical cankers, there was no certainty that the fungus *Gloeosporium perennans* was present in each of them, or, if present, that it was abundant. So, it seemed possible that there might be some other cause or special condition back of the presence of *G. perennans* or possibly some other organism was responsible for the presence of the cankers.

STUDY OF CANKER ADVANCE IN WASHINGTON, D. C.

As the writer's work on this problem was begun in Washington, D. C., in the late fall of 1928, and as the younger parts of the cankers had been developing since spring, the isolations in fall and winter had been made from rather old tissues. In view of the results the writer thought it ad-

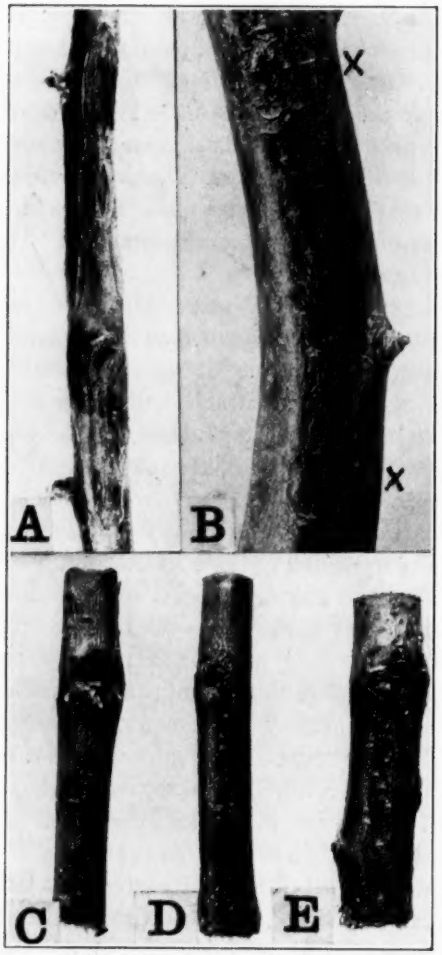

FIG. 2. Artificial and natural cankers on apple stems. A. Stem of Yellow Newtown apple inoculated with Newtown No. 1 (a white bacterium) June 3, 1929, and photographed Aug. 12, 1929. ×½. B. Button stage of canker from Wenatchee, Wash., shown at X. ×1. Isolations made from these March, 1929. C–E. Stems of Yellow Newtown apple inoculated June 25, 1929, and photographed Aug. 10, 1929. ×½. C. Inoculated with pure culture of *Gloeosporium perennans;* D. Control punctures; E. Inoculated with pure culture of white bacterium (strain Newtown No. 1).

visable for further work to use the young canker tissue that starts in the spring to develop beyond the old canker. Thus, the dissatisfaction felt about isolating *Gloeosporium perennans* only infrequently from cankers could be cleared away with the use of young canker tissue, where its presence could be assumed to be certain. If one particular organism were the

cause of the disease, and that one *G. perennans*, it ought to be abundant in the advancing canker tissue.

Therefore, in the spring of 1929, an intensive study of young-canker advance was made with fresh material sent to Washington, D. C., from the Hood River Valley in Oregon. Freehand sections of this canker material were studied under the microscope; some of it was stained and studied, but no *Gloeosporium perennans* or other fungus organism could be located. Many isolation plates were made, but no fungus appeared on them. Frequently, colonies of the white bacterium previously noted appeared, but they were not numerous, as with isolations from old cankers. The work continued in Washington through April and most of May, and from 10 different platings, including 80 plates, no *G. perennans* or other fungi were isolated.

The canker advance in Oregon. Because of the failure to isolate *Gloeosporium perennans* from the canker advance in Washington, D. C., and the failure to induce infection on apple trees by inoculating with either pure cultures of that fungus or spores of the fungus taken from sori on cankers, the idea began to obtain that there must be some regional conditions in the West that bore an active part in the production of the disease. Consequently, further work with the canker advance was transferred to Oregon and continued there from the latter part of May to the middle of August, 1929.

In Oregon suitable canker-advance material for isolations was directly procured from the trees and used immediately, but with the same results as were obtained in Washington, D. C. Even when the youngest and freshest material available was used, no *Gloeosporium perennans* was isolated from the new advance of the cankers until the tissues had darkened and were dying. Then, as in the Washington, D. C., isolations from old cankers, other fungi besides *G. perennans* were found present in this tissue. Dematium, Alternaria, and Fusarium, and, in addition, Cladosporium and occasionally a Penicillium, were present. Twelve sets of plates were poured. The first fungus to appear on the plates poured from the canker-advance material was Alternaria, which appeared on plates poured July 16, 1929. *G. perennans*, Fusarium, and Dematium appeared on plates poured July 23, 1929.

The frequent appearance of the white bacterium on the isolation plates of both spring advance growth and old cankers made the writer suspect it might play a part in the production of cankers. So, this organism and the fungi associated with it so frequently on the plates poured from old cankers were used in Oregon for inoculations into susceptible trees. It might be stated here that in all the inoculations and injections made in Oregon the

stems were first sprayed with $HgCl_2$ and then with water, or the stems were washed with $HgCl_2$ followed by a washing with water. The $HgCl_2$ was allowed to remain on for a minute or more to kill or weaken the various organisms that might be adhering to the surface before the inoculum was applied and before the punctures were made. Inoculations were made mostly with a fine needle. Each of the organisms, Fusarium, Alternaria, Dematium, and the white bacterium, together with its yellow sport, was able to produce canker lesions. The cankers produced by the white bacterium were the largest. When this organism was inoculated into an apple stem 1 to 5 years old, immediately after it was isolated from a canker, it produced a fresh canker nearly 3 cm. long, in 3 weeks. In 2 months a few of the lesions were as large as the natural cankers (Fig. 2, A). One produced in this way and sent to Washington, D. C., from which a water-color drawing was made, was 9 cm. in length. These cankers were produced on a Yellow Newtown tree, located in the last row in the orchard at the top of a hill and therefore exposed to extremes of temperature. The stems may have been weakened by winter injury, although it was not apparent on the surface. The white bacterium was reisolated from a portion of this canker in October, 1929, and again in May, 1931. The stem had been kept in the refrigerator at a temperature around 12° C. during the interval of nearly 2 years. No fungus colonies appeared on the reisolation plates. The culture of the white bacterium producing this canker was kept alive in subculture and its virulence tried out in the same orchard after it was a year old (1930). Lesions 3 cm. long were produced in 3 months. This was appreciably smaller than those produced the year before when the bacterium was first isolated.

For controls, 80 groups of punctures were made with a sterile needle on Newtown apple stems after first spraying them for 1 to 2 minutes with $HgCl_2$ 1–1,000, followed by a thorough spraying with sterile water. Seventy-five other groups of control punctures were made in which the surface of the stems was not sterilized. No lesions followed puncturing the sterilized stems, but 19 small cankers 6 mm. to 2 cm. long appeared on the nonsterilized stems in 2 weeks to 2 months.

The other apple stems inoculated in 1929 with the bacterial organism that produced cankers such as are shown in figure 2 were examined in 1930. No apparent increase in size was made during the spring of 1930. A fissure and callus surrounded the cankers on large stems; some of the small stems inoculated were dead probably because of winter killing through the canker openings. Some of the cankers on 3- to 5-year stems had healed except for central, small, dark areas, while a few on stems of the same age showed entire recovery. The inoculations with the other organisms had similar histories.

INOCULATIONS MADE INTO TREES IN A NONIRRIGATED ORCHARD

About 8 miles from Hood River there was an abandoned apple orchard on a hillside at an elevation of about 1,200 ft. that had never been under irrigation. The trees were 10 to 15 ft. high, and, although in poor condition, were bearing fruit. Three different bacterial species isolated from different cankers were inoculated into Jonathan and Esopus Spitzenburg trees the first of July to see if any infection might occur under the prevalent hot, dry conditions. No inoculations were made with fungi. Two strains of the white bacterium were used, 1 that had been isolated for over 6 months and the other less than 2 weeks. Eighty inoculations were made with the old strain, and 18 with the new one. No infections resulted from the former, but the latter produced 15 lesions, the largest of which was a little over 1 cm. long at the end of a month. The following spring the lesions were 2 to 4 cm. across and appeared as typical cankers. The development had occurred during the fall. Twenty-five inoculations made with the 2 other bacterial species were negative, as were the 67 groups of control punctures.

INOCULATIONS WITH A MIXED CULTURE

Shortly after it was first isolated, the white bacterium was inoculated into a Bartlett pear tree and small lesions developed on young twigs in 2 weeks. They did not enlarge, however, like those on the apple trees. The white bacterium in its active stage was mixed with a fresh isolation of *Gloeosporium perennans* and both pear and apple trees were inoculated with the mixed culture. Controls were held on both trees by inoculating with *G. perennans* alone and the white bacteria alone. This was done in July, 1929, and by the middle of August the largest lesion from the mixed culture on the apple tree was 2 cm. long. The largest on the pear tree was 1 cm. long. No observations were made again until the following April. At that time the cankers had developed further and were larger than those produced either by *G. perennans* alone or the bacterium alone. The largest canker from mixed inoculation on an apple tree was 3 cm. x 2½ cm. No advance had taken place in the spring and a callus had formed around the margins of the canker. The development must have been during the fall or winter. The controls on the apple tree made by inoculating with *G. perennans* alone produced cankers 1 to 1¼ cm. long; the control inoculations made with the white bacterium alone produced cankers 1 to 2 cm. long; both series produced smaller cankers than the inoculations with mixed cultures. The pear cankers produced by the mixed culture had also increased in size and were strikingly different from those inoculated with *G. perennans* alone or the white bacterium alone. There was no spring

advance, however, and the development on the pear stem, as in the apple, must have occurred during the fall or winter. The largest individual canker was 2 cm. long. In the case of both the apple and pear trees several inoculations had coalesced, giving an appearance of a solid canker 4 to 5 cm. long.

The control inoculations on the pear tree, using the 2 organisms alone, bore the same relation to the results with the mixed culture as in the case of the control apple tree; that is, the mixed culture produced the largest cankers.

At the time the various other fungi were inoculated into apple trees, inoculations were likewise made with both old and new isolation colonies of *Gloeosporium perennans*. The colony that had been isolated the previous fall seemed inactive, but the one recently isolated produced cankers in 15 days (Fig. 2, C), although there was only a small percentage of takes. This was usually the case with all organisms tested; there was always less than 50 per cent infection (Table 1). Control punctures and inoculations with the white bacterium were made at the same time as the inoculations with *G. perennans* (Fig. 2, D and E). The fact that several organisms could cause similar lesions on the apple tree and that there were unknown factors that influenced the susceptibility of the stem continued to point to some physiological condition as an important factor in the causation of the disease. This conclusion was reached before the close of the summer of 1929.

INOCULATIONS IN OREGON IN 1930

The inoculations with the various organisms in Oregon, in 1930, were made almost entirely with the isolations of the year before. The organisms had been kept alive by subcultures during the interval, for, at the time, it was not thought necessary to make new isolations. Fresh isolations of these mildly parasitic organisms must, however, carry with them more pathogenic power, for the cankers produced by inoculations in the spring of 1930 were smaller than those produced in 1929 (Table 1). When examined in the summer of 1931[2] most of the cankers, which were recorded by number, had healed over and only a few millimeters of dead areas remained. *Gloeosporium perennans* was among those healed over. The 21 definite canker lesions that were present were mostly under 1½ cm. long; the largest was 3 cm. Since the inoculations bearing these numbers were not recorded with lesions in the summer of 1930, they must have been slower developments that took place in the following fall. The largest canker lesions recorded in 1931 were from inoculations with the fungus Dematium.

[2] Detailed, careful notes were made for the writer in August, 1931, by Mr. E. V. Shear, Associate Pathologist, U. S. Fruit Disease Field Station, Hood River, Oregon.

TABLE 1.—*Inoculations into Yellow Newtown apple trees in Oregon, in 1929*[a]

Organism	Number of inoculations	Cankers produced	Size
Bacteria (4 species)	477	158	1 cm. to 15 cm.
Gloeosporium perennans	84	23	1 " to 2½ "
Fungi (2 other genera)	47	12	8 mm. to 1¾ "
Total	608	193	
Controls			
Stems washed with $HgCl_2$ 1–1,000 and water	80	0	
Stems not washed with $HgCl_2$ 1–1,000 and water	75	19	6 mm. to 2 cm.
Inoculations in Oregon in 1930			
Bacteria (4 species)	68	19	8 mm. to 3 cm.
Gloeosporium perennans	38	7	8 " to 2 "
Fungi, 7 others	231	64	6 " to 2½ "
Total	337	90	
Controls			
Stems washed with $HgCl_2$ 1–1000 and then with water	33	0	
Stems not washed with $HgCl_2$ 1–1,000 and then with water	25	no cankers but some dead areas 4 to 5 mm.	

[a] In 1929 80 per cent of the inoculated stems were wrapped with oiled paper in which a piece of moist cotton was enclosed. This was done because of the dry winds, which not only desiccated the inoculum but carried spore-laden dust.

In 1930 about 50 per cent of the inoculated stems (and injected stems in table 2) were wrapped with oiled paper and the ends of the wraps waxed to prevent evaporation and the entrance of aphids.

It may be stated here that almost no natural cankers occurred in the Hood River Valley orchards during the spring and summer of 1931, nor was there canker development from old cankers already present. The winter of 1930–31 was a mild one and the trees were not injured by cold.

ISOLATIONS FROM WINTER-INJURED CALLUS TISSUE

Apple-canker material was collected in January and February, 1930, in the White Salmon Valley, Washington, a few miles from the Hood River Valley in Oregon, and sent to Washington, D. C., for investigation. The calluses had been well formed but winter injury had killed the tissue at the edges of the callus. There were no sori present on the dead areas and

the specimens did not look like perennial canker. Some of the inner cambium was alive and some dead. Six sets of plates were poured from the winter-injured callus of several stems, and from these plates Fusarium, Gloeosporium, Alternaria, and the white bacterium were isolated. Alternaria was the most abundant. Winter-injured callus on apple trees, it seems, may have one or more organisms present in the dead or dying tissue, among which *Gloeosporium perennans* may or may not be present.

Isolations from cankers on small apple stems. Stems ½ inch in diameter from Hood River Valley, with canker wounds extending halfway through them, were received in Washington, D. C., in January, 1930. Plates were made, using the inner bark and the wood of the cankered tissue. Pieces of material were sterilized ½ to ¾ min. in $HgCl_2$, washed in sterile water, and placed on hardened potato-dextrose agar. Fifty small pieces of the wood from the cankers were treated in this way and 40 pieces of the inner bark. The plates were observed for 12 days. *Gloeosporium perennans* grew from 4 of the 50 pieces of the wood tissue, Alternaria from 2 pieces, and the white bacterium from 4 of the 50 pieces of wood. The rest of the pieces were sterile. The organisms growing from the inner bark were as follows: *G. perennans* grew from 5 of the 40 pieces, Alternaria grew from 3, and the white bacterium grew from 12; the remainder of the pieces were sterile.

EXPERIMENTS WITH CANKER FILTRATES, ENZYMES, ETC.

Because the definite canker-advance tissues did not contain the fungus *Gloeosporium perannans* or other fungus until July or when the canker-advance tissue had darkened and appeared to be dead or dying, it was thought that perhaps this advance might be due to the action of an enzyme produced by the fungus present in the old part of the canker, or else by a by-product of the dead canker tissue. To test this some typical cankers were ground up, mixed with water, and filtered through a Chamberland filter. The filtrate tested for sterility by the poured-plate method was found to be sterile. Some of it was then injected into stems of susceptible apple trees. Likewise, enzymotic material was isolated from crushed cankers, dissolved in water, and injected into stems of susceptible apple trees. In addition, liquid cultures of *G. perennans* separated from the fungus growth and filtered through a Chamberland filter were also injected into apple trees. The filtrate from carrots rotted with *Bacillus carotovorus* was also injected into apple trees, and sterile water into other apple trees for controls. No cankers occurred from a total of 350 injections that were made into trees, both in Virginia and Oregon (Table 2). With the *carotovorus* filtrate 6 of the 52 injections made in Oregon produced lesions with dead tissues ½ to 1 cm. in length and 4 to 5 mm. wide, in a little over a

month. They were not cankers but showed that some of the apple-stem tissue was affected by the presence of this filtrate.

INOCULATIONS IN VIRGINIA IN 1930–31

Jonathan apple trees in Virginia were inoculated with the same organisms used in Oregon. The fungus *Gloeosporium perennans* was not used for inoculations as the belief was prevalent that it was the sole cause of perennial canker of apple trees and therefore should not be introduced into the Eastern States. However, 2 other Gloeosporiums were used—*G. cyclaminis* and *G. musarum*. The inoculations were made each month of the fall and winter of 1930 and the spring of 1931, and continued through the month of May. The work was repeated monthly in order to subject freshly inoculated stems to various weather conditions to see what the effect might be. A total of 1,401 inoculations were made with 219 groups of control pricks made with a sterile needle. Some of the inoculated and control stems were wrapped with oiled paper, others left unwrapped.

No canker was produced by any of these inoculations in Virginia (Table 3). Except in a relatively few cases, there was no evidence on the surface of the stems of any reaction from the inoculations. However, when the bark was cut into at the inoculation places there was usually a darkened area that did not extend into the wood, or, if it did, only to a very slight extent. The bark evidently acted as a medium for the organism to live in for in every case where reisolations were made from this dark tissue the organism could be recovered. Reisolations were made and the organism recovered in the case of 9 different organisms. There were 19 cases where there were indications of tiny lesions on the surface. The tissue had sunk a little and was darker than the surrounding tissue for a centimeter or less, and in a few cases this area was outlined by a fissure. These few simulated what was designated in Washington State as the button type of canker. Seventeen of the 19 lesions came from inoculations made in October and November; the other 2 were from March inoculations. Both fungi and bacteria produced these little lesions. Darkened areas usually surrounded the control punctures but they were only a few millimeters in extent. The fungi and bacteria evidently used the bark of the Jonathan trees in Virginia as a medium on which to live but did not produce cankers. Reisolations were made from the discolored inoculated areas 1 to several months after inoculations were made, and, as stated above, the organism could always be recovered.

DISCUSSION

The frequent absence of *Gloeosporium perennans* from a typical perennial apple canker as well as the frequent presence of various other organ-

TABLE 2.—*Hypodermic injections into Yellow Newtown apple trees in Oregon in 1930, with various sterile solutions, etc.*

Material used for injections	Number of injections	Number of lesions	Size and character of lesions
Filtrate of crushed canker			
In Oregon	56	2	A few mm. long and no appearance of canker
" Virginia	22	0	
Total	78	2	
Filtrate of liquid culture of Gloeosporium perennas			
In Oregon	75	5	A narrow line of dead tissue 5 mm. to 1 cm. long unlike canker in appearance
" Virginia	25	0	
Total	100	5	
Filtrate of Bacillus carotovorus culture			
In Oregon	52	6	5 mm. to 1 cm. long and 4 to 5 mm. wide
" Virginia	12	0	
Total	64	6	
Enzyme from apple cankers dissolved in water			
In Oregon	82	37	A narrow line of dead tissue 5 mm. to 2½ cm. long
" Virginia	25	0	
Total	107	37	
Sterile sand in water			
In Oregon	43	30	A narrow line of dead tissue 4 mm. to 1 cm. long
" Virginia	none		
Total	43	30	
CONTROLS			
Sterile water			
In Oregon	25	0	
" Virginia	10	0	
Total	35	0	
Liquid synthetic medium	23	Small splits with a dark line	

TABLE 3.—*Inoculations into Jonathan apple trees in Virginia in 1930–31*[a]

Organism	Number of inoculations	Number of cankers	Surface markings
Bacteria (4 species)	406	0	7 with dark areas 1 cm. and less
Fungi (6 genera including 2 Gloeosporium species but not *G. perennans*)	995	0	12 with dark areas 1 cm. and less
Controls	219	0	

[a] About 50 per cent of the inoculated stems were wrapped with oiled paper; the ends of wraps were not waxed.

isms seemed to indicate that there is some other underlying factor, possibly a physiological one, that is responsible for the disease. The fact that various unrelated organisms could be repeatedly isolated from cankers and that a number of these could artificially reproduce cankers, indicated that the plant tissue must be weakened, a condition brought about by one cause or a combination of causes. The most outstanding and important one seemed to be the condition in which the trees were left after sudden low temperatures in the winter.

The hard freeze of the early part of the winter of 1919–20, when the temperature in the Hood River Valley and other Northwestern apple regions fell to −27° F., produced wide-spread damage in the apple orchards of those regions. The dead and dying tissues that resulted from the freeze were a good medium for the growth and development of *Gloeosporium perennans*, other fungi, and bacteria. *G. perennans*, a weak parasite already common in the region, producing fruit rot in ripe apples (6), became rampant in these orchards. Due to the heavy and widespread destruction of trees or parts of trees by this freeze, the orchards did not get cleared of the dead branches for a year or 2 or even longer. Up to that time the canker was little known and was not feared. The dying branches proved a menace and gave the opportunity for a widespread development of the spores of *G. perennans*, and possibly successive contacts of successive generations of spores with dead apple bark increased its tendency to pathogenicity. The same can be said of the other fungi and bacteria taking up their abode in the dead apple tissue.

Since the winter of 1919–20 it has been noticed that perennial canker is more prevalent and serious in those regions where lower temperatures prevailed the previous winter. The climate of certain fruit-growing sections of the Pacific Northwest is generally mild throughout the winter, with the

exception of occasional hard freezes, which do not occur every year. The winters of 1924 and 1926 were also such severe ones that many trees were weakened and later became prey to this disease. Because of the generally mild climate, the trees do not get hardened off gradually to meet the cold, as in the apple-growing sections of the East. Thus unprepared, the trees, in a more or less succulent condition, become injured to varying degrees by the cold. If the injury is not sufficient to kill, there are devitalizing effects from the cold that make the tissues susceptible to disease. During the period of this investigation there was no typical canker year; if the inoculations with the various organisms had been made after a very severe winter it is quite probable that many more canker lesions would have been produced.

In the literature about perennial canker of apple trees previous to 1930 the possible effect of winter injury is mentioned frequently (1, 2), and in 1930 Fisher and Reeves (7) definitely advised orchardists to prepare their orchards to resist freezing weather because by so doing the trees would be better able to resist perennial-canker infection. They made recommendations for bringing the trees to a hardened condition.

A few of the orchardists in the Hood River Valley already claim to have cured badly cankered trees by proper feeding and their fear of future losses from cankered trees has vanished. If their claim still holds after a few more years have elapsed, the feeding, irrigation, and cultural methods of these orchardists should be put into general use.

According to entomologists, perennial canker usually follows a woolly-aphis infestation; the tissue of young apple stems and the callus of pruning wounds are weakened by the attack of the aphids, permitting the entrance and advance of the *Gloeosporium perennans*. It is doubtless true that woolly-aphis infestation on young callus tissue weakens it so that it is more readily injured by cold weather and later by cankers.

Sprays have been ineffective in controlling the disease, though they no doubt cut down the number of active organisms on the surface that could enter the tissues following winter injury. Crenshaw (5) has thrown light on the effectiveness of sprays by showing how long they can prevent germination of *Gloeosporium perennans* spores under ordinary orchard conditions.

SUMMARY

The fungus *Gloeosporium perennans*, heretofore considered the organism causing the perennial canker of apples in the Northwest, was found frequently absent in otherwise typical cankers. Other fungi were present, also bacteria, sometimes in company with *G. perennans* but just as frequently without it.

These organisms were isolated from typical apple cankers and were inoculated into apple trees in Virginia and in the Hood River Valley, Oregon. No cankers were produced in Virginia, but typical ones were produced in Oregon with Alternaria, Fusarium, Dematium, Cladosporium, Penicillium, and a white bacterium. *G. perennans* did not infect more readily than the other organisms, but field inoculations were made with it only in spring and summer. In some cases there was canker growth during the fall following inoculations made in the spring of 1929, but there was no new canker development the next spring. The inoculations made in the spring of 1930 from year-old isolations of bacteria and fungi were mostly healed over when examined in 1931. Those canker lesions present were small and apparently had developed in the fall from the spring (1930) inoculations.

G. perennans was not used for inoculations in Virginia because of the danger of introducing the disease in a region where it never had occurred. Other species of Gloeosporium, *G. musarum* and *G. cyclaminis*, however, gave negative results when used in Virginia.

In looking for a reason why cankers formed from inoculations made in Oregon and none from inoculations made in Virginia, the writer has concluded that the reason is a local one. There was evidently no active parasite connected with the disease, even though the appearance of the cankers belied it.

It has been noticed since the cold winter of 1919–20 that perennial canker was more extensive in those regions where lower temperatures prevailed. So, judging from field observations made and from evidence obtained from other workers, together with the fact that no cankers occurred following the mild winter of 1930–31, it is concluded that the disease is primarily due to winter injury with woolly aphis as a factor in the injury. The organisms that live in the cankers following this injury could not gain foothold and develop in healthy apple tissue, but the changed conditions in the cells of winter-injured tissues offer a good medium for their growth and development.

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LITERATURE CITED

1. CHILDS, LEROY. Perennial canker of apples. Ann. Rept. Oregon State Hort. Soc. **19** (1927): 108–115. [1928]
2. ———. The relation of woolly apple aphis to perennial canker infection with other notes on the disease. Ore. Agr. Exp. Sta. Bul. 243. 1929.
3. COOLEY, J. S., and P. W. MILLER. Studies of perennial canker disease of the apple. (Abst.) Phytopath. **20**: 851–852. 1930.

4. ————, and E. V. SHEAR. Relation of perennial apple canker to its environment. (Abst.) Phytopath. **21**: 1000. 1931.
5. CRENSHAW, J. H. Measuring duration of effectiveness of Bordeaux sprays to perennial canker spores. (Abst.) Phytopath. **20**: 855. 1930.
6. FISHER, D. F. A new apple rot disease. Proc. Wash. State Hort. Assoc. **21** (1925): 44–48. [1926.]
7. ————, and E. L. REEVES. Perennial canker. Proc. Wash. State Hort. Assoc. **24** (1928): 55–61. [1929.]
8. ————, and ————. Recent studies on perennial canker. Proc. Wash. State Hort. Assoc. **25** (1929): 155–166. [1930.]
9. GÜSSOW, H. T. Perennial apple tree canker. Canada Dept. Agr. Pamph., N.S., 116. 1930.
10. MCLARTY, H. R. Observations on the life history and spread of perennial canker (*Gloeosporium perennans*). Rpt. Canada Exp. Farms (Rpt. Dom. Bot.) **1926**: 136–141. 1927.
11. ZELLER, S. M., and LEROY CHILDS. Perennial canker of apple trees. Ore. Agr. Exp. Sta. Bul. 217. 1925.

ZINC–LIME: A FUNGICIDE FOR THE PEACH

JOHN W. ROBERTS AND LESLIE PIERCE[1]

INTRODUCTION

The first successful fungicide for general use on the peach during the growing season was the so-called self-boiled lime-sulphur mixture introduced by Scott (10) in 1907. Since that time many substitutes for this mixture, all containing elemental sulphur as the active ingredient, have been introduced and successfully used. These sulphur fungicides are excellent protectants against attacks by the brown-rot fungus, *Sclerotinia fructicola* (Wint.) Rehm,[2] and the scab fungus, *Cladosporium carpophilum* Thüm., but are not effective against the bacterial-spot pathogen, *Bacterium pruni* E. F. Smith.

In 1925, at the request of the Purdue University Agricultural Experiment Station and the Knox County Horticultural Society, the writers undertook to develop, at Vincennes, Indiana, a spray that would control peach bacterial spot. Since susceptibility to the disease extends over a long period, it was evident that many applications of spray would be necessary. It was also evident that a fungicide applied so often would have to be practically noninjurious to the peach to avoid a serious accumulation of spray injury. Of the 200 mixtures and combinations tested, one, composed essentially of zinc sulphate and hydrated lime in water and referred to in this paper as zinc-lime, has consistently given the best results. The writers first reported upon this mixture as a control for bacterial spot of peach in 1929 (2). More complete reports were later published in the Proceedings of Horticultural Societies (3, 4, 5, 6, 7, 8) and in the American Fruit Grower Magazine (9). These papers reported results with zinc-lime on the control of bacterial spot and stimulation of the peach. They also reported favorably on the use of arsenate of lead with zinc-lime but reported no decisive results on experiments for the control of scab and brown rot.

This paper is a report of experiments to determine the possible usefulness of the spray as a complete fungicide for use on peaches during the growing season. The term "fungicide" is here used to include substances toxic to the organisms causing bacterial spot, scab, and brown rot, and noninjurious or relatively noninjurious to the peach in active growing condition.

[1] The writers thank members of the Knox County, Indiana, Horticultural Society and the Purdue University Agricultural Experiment Station, particularly M. W. Gardner, C. L. Burkholder, and Arthur Goss, for their cooperation and encouragement in the development of this spray.

[2] Also named *S. americana* (Wormald) Norton and Ezekiel and considered by some as not specifically distinct from *S. cinerea* (Bon.) Schröt.

THE ZINC-LIME SPRAY

The name zinc-lime is applied to a mixture of zinc sulphate, lime, and water. Zinc-lime, 4–4–50, denotes a mixture of 4 lbs. of zinc sulphate ($ZnSO_4 \cdot 7H_2O$) and 4 lbs. of hydrated lime in 50 gals. of water. The name zinc-lime was adopted after several trials. First, the name zinc-Bordeaux-mixture was tried but was abandoned because it was taken by some to indicate the presence of a copper salt. A trial of the name zinc sulphate spray caused one grower to omit the lime, with, of course, disastrous results. The name zinc-lime was then adopted because it is short, easily remembered, and suggests the composition of the spray.

As first used by the writers, either casein-lime or alum was added to zinc-lime. Gradually, however, the simple formula 4–4–50, without an additional substance, was adopted. The casein-lime was dropped because it seemed not to lessen the settling time of the precipitate and not to add to the sticking and spreading qualities of the mixture. Alum, when added to the mixture, produces a precipitate that lessens the settling time, but in laboratory tests the addition of an alum greatly decreased the toxicity of zinc-lime to conidia of the peach brown-rot and scab fungi. In these tests zinc-lime, 4–4–50, prevented germination of brown-rot conidia and stopped the growth of germ tubes from scab conidia directly after germination. Zinc-lime, 4–4–50, to which alum was added, did not prevent the germination of brown-rot conidia, though it inhibited somewhat the growth of germ tubes and only slightly checked the growth of germ tubes from scab conidia.

The substitution of sodium carbonate for hydrated lime or of zinc chloride for zinc sulphate has resulted in severe injury to the peach.

The following is recommended as a standard formula for the zinc-lime spray, but the proportions of zinc sulphate and hydrated lime to water may be increased at least to 8–8–50 if desired, without causing injury. However, proportionately better results have not followed the use of a mixture stronger than the one here recommended.

Zinc sulphate	4 lbs.
Hydrated lime	4 lbs.
Water	50 gals.

Zinc sulphate ($ZnSO_4 \cdot 7H_2O$), sometimes called granular zinc sulphate or white vitriol, is a common chemical easily obtained. A so-called anhydrous zinc sulphate is sometimes found on the market. This product is not anhydrous but contains, in varying quantities, less water than the granular zinc sulphate and is more easily handled because it is relatively free from lumps. For practical purposes, 3 lbs. of the so-called anhydrous zinc sulphate may be considered equal to 4 lbs. of the ordinary granular

zinc sulphate, provided it is stored in a dry place and kept well covered so that it does not absorb water.

The hydrated lime should be fresh and of high quality. The grade known in the trade as "chemical" is especially recommended.

The spray is prepared as follows: Fill the tank nearly full of water. Start the engine to give agitation. Add the zinc sulphate, which, if the lumps are well broken up, will dissolve in less than 5 minutes. After it has dissolved, the lime mixed with a small quantity of water to form a thin paste should be washed through the strainer into the tank. Finish filling the tank and agitate for 5 minutes or more before beginning to spray. The white precipitate settles somewhat rapidly but is easily kept in suspension by agitation. Use at once.

The chemical reactions taking place in the preparation of zinc-lime are not know to the writers. It is supposed that basic sulphates of zinc are formed. According to Pickering (1), who made a study of the chemical reactions in mixtures of this type, "The general character of the reaction appears to be similar with all the metallic sulphates examined, and with all the caustic alkalis. The metal is first precipitated as a basic sulphate of definite composition, which, on the addition of more alkali, is converted into a second, more highly basic sulphate, before any alkaline reaction becomes evident in the liquid. In some cases, the transformation takes place in two distinct stages.

"In every instance examined the products of the reaction, so far as the basicity of the precipitates is concerned, are the same, whether soda or lime is used, but the precipitates are not always identical in other respects, and this has been ascertained to be due to the fact that, when lime is used, they retain a considerable amount of the calcium sulphate formed in the reaction. . . . .

"With zinc sulphate and soda, the complete precipitation of the metal was coincident with the appearance of a permanent alkaline reaction, and no preliminary or secondary reaction was noticed. The alkali required was found to be 0.795 equivalent, indicating, therefore, the composition of the precipitate to be $5ZnO, SO_3$."

EXPERIMENTS IN THE CONTROL OF BACTERIAL SPOT

Zinc-lime has given excellent results in the control of bacterial spot in orchards where its use has been supplemented by the employment of good cultural methods. Because peach trees lacking in vigor are especially susceptible to the disease, it is important that this unfavorable factor be overcome in so far as possible by good cultural practices. In spraying for the control of the disease it is important that the fruits and the underside of leaves be covered because the stomata are infection portals. Incidentally,

the covering of the young twigs probably prevents the formation of new bacterial spot cankers. Spraying with zinc-lime for the control of bacterial spot has restored the productiveness of trees that had been weakened by premature defoliation year after year and consequently had developed few fruit buds.

In addition to the experiments of 1928 and 1929 previously reported (2, 3, 4, 5, 6, 7, 8, 9), tests of zinc-lime as a preventive of bacterial spot were carried out at Vincennes, Indiana, in 1930 and 1931. In 1930 there was no crop but, despite the relatively dry season, results in the control of the disease on the leaves were obtained. In addition, notes on the effects of frequent applications of zinc-lime to peach trees were obtained. The experiments, as carried out, are outlined in table 1.

TABLE 1.—*Composition and times of application of spray and dust materials used in experiments for the control of bacterial spot on peach leaves. Vincennes, Indiana, 1930*

Plot	Number of trees	Composition of mixtures[a]	Dates of application
1	60	Zinc-lime, 4–4–50	April 26, May 9, May 21, June 4, June 19, July 7
2	36	" " 4–4–50 + casein-lime ½ lb.	"
3	36	" " 8–8–50	"
4	32	" " 4–4–50 + wettable sulphur 2 lbs.	"
5	20	" " 4–4–50 + copper sulphate ½ lb.	"
6	20	Hydrated lime 4 lbs., water 50 gals.	"
6A	20	" " 15 lbs., " 50 gals.	"
7	24	Dust: monohydrated zinc sulphate 30% hydrated lime 70%	"
8	24	Dust: basic zinc sulphate 20%, sulphur 65%, hydrated lime 15% (a commercial mixture)	"
9	24	Zinc-lime, 4–4–50	April 26, May 5, 9, 16, 22, 31, June 7, 13, 19, July 1, 7, 16
10	24	" " 4–4–50	May 9, 16, 21, 31, June 13, July 1, 16
11	24	Control	Not sprayed

[a] Arsenate of lead was included in 2 applications on all plots. On dust plots it was substituted for part of the hydrated lime.

Bacterial spot was first noted May 8 on leaves of one of the controls. On May 14 a considerable number of infected leaves and a trace of defoliation were noted in the control plot. No infected leaves were found in the zinc-lime-sprayed plots. By June 27 infected leaves were present on all the control trees but none could be found in the zinc-lime-sprayed plots. On July 2 it was estimated that many of the controls had 10 per cent of their leaves infected. There were practically no infected leaves in the zinc-

TABLE 2.—*Results of an experiment to determine the effectiveness of zinc-lime in the control of bacterial spot of peach fruits. Vincennes, Indiana, 1931*

Plot	Variety	Number of trees	Composition of spray or dust[a]	Number of applications	Total fruit	Percentage of fruits having bacterial spot				Percentage of fruit merchantable
						Mild[b]	Moderate	Severe	Total	
1	J. H. Hale	6	Zinc-lime 4–4–50	6	4379	7	0	0	7	100
2	"	6	" " 4–4–50 + casein-lime ½ lb.	6	4352	35	2	1	38	97
5	"	6	" " 4–4–50 + liquid licorice extract 2 lbs.	6	5780	29	2	1	32	97
6	"	6	" " 4–4–50 + paste sulphur 2 lbs.	6	4813	20	1	1	22	98
8	"	6	Dust: monohydrate zinc sulphate 30% hydrated lime 70%	6	3477	15	2	2	19	96
9	"	6	Dust: a commercial dust containing zinc compounds	6	4435	20	2	4	26	94
10	"	6	Zinc-lime 4–4–50	11	5506	26	1	1	28	98
11	"	6	Control: sulphur dust	3	4572	39	8	10	57	82
12	Elberta	12	Zinc-lime 4–4–50	6	9043	17	1	1	19	98
13	"	6	Control	.....	5605	34	4	4	42	92

[a] Arsenate of lead in 2 applications for each plot.

[b] Mild, spots inconspicuous and few; moderate, spots conspicuous but few; severe, spots conspicuous, numerous, causing disfigurement. Only the mild was merchantable.

lime-sprayed plots. On July 5 it was estimated that, on the average, the trees of the control plot had lost 5 times as many leaves as those of plot 1. On October 2 the estimated defoliation of the control trees was 15 per cent with about 20 per cent of the remaining leaves infected. At that time defoliation in the zinc-lime-sprayed plots was estimated at 2 per cent with 10 per cent of the remaining leaves infected. Plot 3, the zinc-lime 8–8–50 plot, and plot 9, receiving 12 applications of zinc-lime 4–4–50, were almost free of bacterial spot throughout the season. On October 2 the foliage of these plots was a rich, dark green, and uninjured. The copper caused injury to foliage in plot 5. In plot 4 the addition of wettable sulphur possibly reduced slightly the sticking properties and effectiveness of the zinc-lime. Neither the dust plots nor the lime plots gave any indications of controlling the disease. They were not superior to the control plot.

In 1931, at Vincennes, there was a heavy crop of fruit in the experimental plots, as indicated in table 2, which shows the results of experiments in the control of the disease on fruit. On all but Plot 10, applications of spray or dust were made at intervals of 2 weeks, beginning at petal fall. It will be noted that the number of infected fruits was much less on the zinc-lime plots and that nearly all the infections on the fruit of these plots were classified as mild. The first leaves showing bacterial spot were collected May 4, and the first fruit June 9. On June 19 the control trees showed slight defoliation. A small percentage of the fruit of these trees showed infection, but no infected fruit could be found on the trees sprayed with zinc-lime. On June 26 many of the nonsprayed Elberta trees had as many as 50 per cent of their leaves and many fruits infected. There was a noticeable number of infected leaves on some of the zinc-lime-sprayed Hale and Elberta trees and a trace of defoliation, but the fruit and foliage of plot 1 were nearly free of infection. During July the development of bacterial spot was apparently checked by the hot, dry weather but was favored by more rain and cooler weather in August. At the beginning of fruit harvest, August 24, defoliation on plot 1 was estimated to be 5 per cent, on plot 2, 20 per cent, and on the remaining zinc-lime-sprayed plots, 10 per cent. On plots 8 and 9, the zinc-lime-dust plots, and on the control, defoliation was estimated to be 35 per cent.

The orchard used in these experiments is on light, sandy soil and, in its earlier years, was annually defoliated by bacterial spot. By use of leguminous cover crops and the zinc-lime spray, defoliation in later years has been largely prevented and, consequently, the trees have become vigorous and productive.

EXPERIMENTS IN THE CONTROL OF SCAB

Since scab was either absent or of slight importance in the Indiana and Arkansas orchards in which the bacterial-spot-control experiments were

performed, experiments in control were conducted at Arlington Farm, Rosslyn, Virginia, in 1930 and 1931. Trees known to have been heavily infested with scab in previous years were selected and a large limb on each tree received applications of zinc-lime 4–4–50.

In 1930 the unprecedented drought caused infection of the fruit to be so light that results were not recorded. In 1931 rains in July and August were favorable for a moderate infestation and results were recorded.

Six seedling and 6 budded peach trees were used in the 1931 experiment. In all cases, a limb adjacent to the sprayed limb and of about the same size and the same distance from the ground, was used as a check or control. A small hand pump rather than a larger outfit was used in order to confine the spray to the selected limbs.

The applications concerned in scab control were made (1) May 27, (2) June 19, (3) July 13. Six trees received all 3 applications, and 6 received only the 1st and 3rd.

Because of severe hail injury in late July, records had to be taken about 1 week before ripening in anticipation of a masking of the scab spots by the brown rot that usually follows late-season hail injury. Results from 1 of the budded trees were not taken because no scab developed, even on the nonsprayed limbs. Factors unfavorable to control, which do not exist in commercial practice, were: (1) the nonsprayed part of the tree was a potential infection source for the sprayed fruit; (2) the small hand pump did not give good coverage, principally because it did not give pressure sufficient to blow aside the leaves that covered the fruit.

In recording results a peach was counted as scabby even if it had but 1 scab spot. A peach with more than 5 spots was recorded as severely scabbed. Many of the control fruits, especially those of the late-season varieties, were half-covered with a crust of coalesced scab spots. This was particularly true of the Heath Cling variety which, because its fruit ripens late in the season, should have received an additional application in August. Table 3 is a summary of the results. In this table a sprayed limb and a control on the same tree are given the same plot number.

It appears from these results that the application made June 19 had little effect on scab control. Very little scab developed until late in July, when frequent rains, in contrast with the bright sunny weather of spring and early summer, favored development. The results are fairly consistent and indicate that zinc-lime can be depended upon to control at least moderate outbreaks of scab.

EXPERIMENTS IN THE CONTROL OF BROWN ROT

Results in the control of brown rot are not conclusive but indicate that zinc-lime will definitely check and probably control the disease. In experi-

TABLE 3.—*Results of spraying peach trees with zinc-lime 4–4–50 for the control of scab (Cladosporium carpophilum). Arlington Farm, Rosslyn, Virginia, 1931*

Plot	Variety	Dates sprayed	Fruit		
			Total	Percentage having scab	Percentage having severe scab
1	Unnamed seedling	May 27, July 13	39	18	0
1A	" "	Control	24	54	0
2	" "	May 27, July 13	28	50	0
2A	" "	Control	27	100	78
3	" "	May 27, July 13	62	34	3
3A	" "	Control	32	59	6
4	" "	May 27, June 19, July 13	19	47	11
4A	" "	Control	12	67	33
5	" "	May 27, June 19, July 13	87	28	0
5A	" "	Control	21	71	19
6	" "	May 27, June 19, July 13	102	35	3
6A	" "	Control	58	79	26
7	Heath Cling	May 27, June 19, July 13	78	47	18
7A	" "	Control	71	100	93
8	Early Elberta	May 27, June 19, July 13	91	1	0
8A	" "	Control	82	46	9
9	Belle	May 27, June 19, July 13	140	6	0
9A	"	Control	71	25	0
10	"	May 27, July 13	88	28	0
10A	"	Control	76	22	9
11	Carman	May 27, July 13	107	8	0
11A	"	Control	95	52	3
All sprayed plots		.....	841	23	3
All control plots		.....	569	57	23

ments for the control of brown rot as an orchard disease the reliability of the results is frequently under suspicion because of the relation of the disease to insect attacks and to moisture conditions, both of which may vary greatly in different parts of an orchard. Probably storage tests of the picked fruit from plots variously treated give more reliable results than those obtained from examination of newly picked fruits. In storage tests, all wormy fruit is thrown out, and an attempt can be made to use fruit of the same degree of ripeness. Also the fruit from all plots can be kept under the same conditions of temperature and moisture.

In 1928, in Vincennes, Indiana, records on brown rot were taken, together with those on bacterial spot, for the control of which the experiment was primarily designed. The zinc-lime plot of J. H. Hale peaches was sprayed 6 times, but only the last application, which was made on July 16, would be effective against brown rot. The variety J. H. Hale regularly

matures a crop of large spherical "normal" fruits followed 2 to 3 weeks later by the small elongated fruits, which, in Indiana, are called "nubbins." The results of spraying both normal fruit and nubbins for the control of brown rot, shown in table 4, indicate success in checking loss from brown rot

TABLE 4.—*Results of experiments on the control of peach brown rot by means of zinc-lime sprays applied April 26, May 11, May 25, June 12, June 30, July 16. Vincennes, Indiana, 1928. Picked fruit of the J. H. Hale variety*

Plot No.	Number of trees	Composition of spray	Normal fruit picked Aug. 20–25		"Nubbin" fruit picked Sept. 10–11	
			Total	Percentage rotted	Total	Percentage rotted
1	9	Zinc-lime, 4–3–50, + casein-lime ½ lb.	1467	3	1137	9
2	6	Control	328	8	1034	21

on both normal fruit and nubbins. There was no wormy fruit on either sprayed or control trees to complicate the results.

In 1929, at Springdale, Arkansas,[3] one plot in an orchard of 16-year-old Elbertas was sprayed 7 times for the control of bacterial spot, while the control plot received the usual applications of self-boiled lime-sulphur for the control of brown rot and scab. The last application of spray was made July 16, and the fruit, which ripened very unevenly, was picked August 5 to 19. The trees were hard to spray, being large, even for their age, and closely planted. In the zinc-lime plot there were 103 trees, while the remainder of the orchard comprised the control plot.

In the zinc-lime plot the crop of 10 trees and in the control the crop of 12 trees were examined for brown rot. The results, as shown in the 2 upper rows of table 5, are not very convincing, but when a group of trees in the zinc-lime plot is compared with an adjacent group in the sulphur plot, as is done in the last 4 rows of the table, there is little choice between the zinc-lime and sulphur sprays. The failure of both to give better results was probably due to the previously mentioned difficulties in applying the sprays.

In 1929, at Vincennes, Indiana, there was not enough brown rot in the experimental orchards at picking time to yield results worth recording, but there was enough to distribute conidia about the orchard. From a zinc-lime plot and a control plot, J. H. Hale peaches of medium size and

[3] These experiments were carried out by John C. Dunegan, Associate Pathologist, Division of Horticultural Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

TABLE 5.—*A comparison of zinc-lime and self-boiled lime-sulphur sprays for the control of peach brown rot. Picked fruit of the Elberta variety. Springdale, Arkansas, 1929*

Composition of spray	Number of trees	Fruits	
		Total	Percentage rotted
Zinc-lime, 4–3–50, + casein-lime ½ lb.	10	7032	19
Self-boiled lime-sulphur, 8–8–50	12	6052	12
Zinc-lime, 4–3–50, + casein-lime ½ lb.	Group 1, 4 trees	1313	46
Self-boiled lime-sulphur, 8–8–50	" 1A, 3 "	384	57
Zinc-lime, 4–3–50, + casein-lime ½ lb.	" 2, 6 "	5719	15
Self-boiled lime-sulphur, 8–8–50	" 2A, 6 "	4874	12

hard ripe were selected and kept in baskets in basement storage without refrigeration directly after picking in August. The zinc-lime plot had received 8 applications of spray, but only the last 1, applied 15 days before picking, would be effective in checking rot of stored fruit. The controls had been sprayed with a commercial wettable sulphur 38 days before picking and were therefore practically unprotected. The results are shown in table 6. Evidently the zinc-lime checked the rot, since the control fruit

TABLE 6.—*Effect of zinc-lime spray, applied 15 days before picking, on the prevention of brown rot. J. H. Hale peaches stored without refrigeration. Vincennes, Indiana, 1929*

Composition of spray	Total fruit	Percentage of brown rot on stored fruit			
		After 2 days	After 4 days	After 7 days	After 10 days
Zinc-lime, 4–3–50, + casein-lime ½ lb.	153	1	25	71	95
Control	139	9	60	91	98

rotted much more rapidly than that sprayed with zinc-lime.

The seasons of 1930 and 1931 were too dry for the development of sufficient brown rot to give results in experimental trials.

EFFECT OF ZINC-LIME SPRAY ON THE PEACH

No injury to the peach by the zinc-lime spray has been noted; even 6 applications at double the strength commonly used in these experiments

caused no injury. (Table 1.) In 1930 the 24 peach trees in the Indiana experiments (Table 1) receiving 12 applications of zinc-lime, 4–4–50, were the most vigorous-appearing trees in the orchard at the end of the season. In 1931 those receiving 11 applications (Table 2) appeared at least as vigorous as any in the orchard.

The fruit of the zinc-lime plots in all trials compared favorably in color with that of trees receiving sulphur sprays. The size and number of fruits appeared to be favorably affected, but whether by control of bacterial spot on the leaves, by foliage stimulation, or by direct effect on the fruit, is not known. Unless deep-green because the trees are already in a high state of vigor, the leaves of zinc-lime-sprayed trees were noticeably a deeper green and often larger than those of the controls that were either not sprayed or sprayed or dusted with other materials. In 1928 leaves from zinc-lime-sprayed trees and from controls, respectively, were measured with a planimeter. Attempts were made to collect leaves of the same age and relative position on zinc-lime-sprayed trees and on controls. The average area of 136 leaves taken from 10 twigs of a zinc-lime-sprayed tree was approximately 0.35 sq. in. larger than that of 123 leaves of an adjacent control. With so many chances for error, these results, of themselves, cannot be considered significant, but they support the field observations.

Zinc-lime-sprayed trees have frequently retained foliage on short laterals long after the leaves had been shed from practically every short lateral on the control trees in July, and in every experiment they have retained their foliage later in the season than the controls. This retention of foliage can be accounted for partly by control of bacterial spot and partly by lack of spray injury, but it has occurred also in orchards in light soil where there was little or no bacterial spot and no apparent spray injury on the control trees. It seems to be due, in part at least, to a stimulation or other physiological effect, wholly apart from control of pathogens or from lack of injury. The stimulative effect of small quantities of zinc on plants is well known. With the zinc-lime sprays the effect seems to be a direct one because it may appear very soon after an application is made and because no quickly apparent results have been obtained from applying solutions of zinc sulphate or the zinc-lime mixture to the soil. The retention of foliage by the peach trees sprayed with zinc-lime is one of the most notable features of the treatment. It is of particular importance for orchards in light soil and subject to bacterial spot and spray injury. Premature defoliation in such orchards not only weakens the trees but frequently reduces the crop for the following year by preventing the fruit buds from maturing.

COMBINATION OF ZINC-LIME WITH OTHER SPRAY MATERIALS

Zinc-lime has been used by the writers in combination with wettable sulphur without apparent injury to peach trees and without appreciably

lessening the efficacy of zinc-lime in the control of bacterial spot. The combination appears to make a satisfactory spray. Many growers have used this combination with apparent success.

In most of the experiments reported upon in this paper arsenate of lead was added to at least 2 of the early-season applications. Arsenate of lead in combination with zinc-lime caused little or no injury, usually much less than when combined with wettable sulphurs and lime or with lime alone. Growers who have used zinc-lime and arsenate of lead in combination have noted much less injury than with the sulphur-arsenate of lead-lime combination. The writers have observed the same differences in orchards commercially sprayed by growers. One large grower uses the zinc-lime and arsenate of lead combination largely for the purpose of avoiding arsenical injury to foliage, twigs, and buds.

In the experiments of 1930 (Table 1) there was considerably more arsenical injury in plot 6A, which received applications of hydrated lime at the extremely high rate of 15 lbs. to 50 gals. of water in combination with arsenate of lead, than in plots 1, 2, 3, and 4, receiving zinc-lime in combination with arsenate of lead.

SUMMARY

In experiments and in commercial orchards zinc-lime, a spray composed of zinc sulphate, hydrated lime, and water, when applied to peach trees, has greatly reduced infection by *Bacterium pruni*. Because infections may occur from early spring till late summer, 5 to 7 applications of the spray were necessary. Because the stomata are infection portals, special care must be taken to cover the underside of leaves. Coverage of young twigs probably prevents formation of new bacterial-spot cankers.

Zinc-lime, in experimental trials on a small scale, has controlled mild and moderately severe cases of peach scab (*Cladosporium carpophilum*), and there are indications that it will, at least, control mild cases of peach brown rot (*Sclerotinia fructicola*). Because its effectiveness against severe cases of scab and brown rot has not been tested, it is not yet known whether it would be as effective as the sulphur sprays under conditions favoring heavy infestation.

Zinc-lime, even at twice the strength here recommended, has not injured fruit, foliage, or any part of the peach tree. On the contrary, it has frequently caused the leaves to become deeper green and larger than those of the controls. There is some indication that fruit development also is stimulated. Trees receiving 12 applications were, at the end of the season, the most vigorous-appearing ones in the orchard.

Arsenate of lead, when combined with zinc-lime, in experimental trials and in commercial use, generally has caused noticeably less injury to

foliage, twigs, and buds than when combined with sulphur fungicides and lime or with lime alone. In experimental trials and in trials by growers a mixture of one of the wettable sulphurs, commonly used on peaches for the control of scab and brown rot, and zinc-lime, when applied to peach trees, caused no apparent injury and seemed not to reduce appreciably the effectiveness of the constituents.

Zinc-lime in dust form was ineffective in the control of bacterial spot on peach leaves and less effective than the spray in the control of the disease on fruit. It has not been tested as a fungicide for the control of brown rot and scab.

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LITERATURE CITED

1. PICKERING, SPENCER UMFREVILLE. The interaction of metallic sulphates and caustic alkalis. Jour. Chem. Soc. **91**: 1981–1988. 1907.
2. ROBERTS, JOHN W., and LESLIE PIERCE. A promising spray for the control of peach bacterial spot. (Abst.) Phytopath. **19**: 106–107. 1929.
3. ————, and ————. Controlling peach bacterial spot. Hoosier Hort. **11**: 6–12. 1929.
4. ————, and ————. Control of peach bacterial spot. Rpt. Md. Agr. Soc. **13** (Rpt. Md. State Hort. Soc. **31**): 153–159. 1929.
5. ————, and ————. Control of peach bacterial spot. Trans. Peninsula Hort. Soc. **42** (Bul. Del. State Bd. Agr. **18** (5)): 102–106. 1929.
6. ————, ————, and JOHN C. DUNEGAN. Control of peach bacterial spot. Trans. Ill. State Hort. Soc. **63**: 423–426. 1929.
7. ————, ————, and ————. Control of peach bacterial spot. Proc. Georgia State Hort. Soc. **53**: 32–35. 1929.
8. ————, ————, and ————. Control of peach bacterial spot. Rpt. Md. Agr. Soc. **14** (Rpt. Md. State Hort. Soc. **32**): 221–226. 1930.
9. ————, ————, and ————. Control of peach bacterial spot. Amer. Fruit Grower Mag. **50** (2): 10–11. 1930.
10. SCOTT, W. M. A promising treatment for brown rot and other peach diseases. Proc. Amer. Pomol. Soc. **30**: 39–45. 1907.

SEED TREATMENTS WITH CHEMICAL DUSTS AND FORMALDEHYDE FOR SMUT CONTROL IN OATS

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INTRODUCTION

The economic importance of smut control in oat production becomes readily apparent when the heavy annual loss caused by the oat-smut pathogens is considered. According to estimates of the plant Disease Survey for the 11-year period 1917–1927, inclusive, for which estimates are available, the average loss from smut in oats in the United States has amounted annually to almost 50,000,000 bushels.[2] In single States, annual loss as high as 10 per cent frequently has been reported. In 1928 the estimated oat-smut loss was 35 per cent in South Carolina and 20 per cent in North Carolina. Within the last few years, moreover, new physiologic forms of the pathogens (*Ustilago avenae* (Pers.) Jens. and *U. levis* (Kell. and Sw.) Magn.) that are taking a heavy toll in hitherto-resistant varieties (16) have appeared.

[1] The writer gratefully acknowledges his indebtedness to Mr. T. R. Stanton, Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, for identifying the oat varieties used in the experiments, and to Messrs. L. L. Davis and R. W. Leukel, of the same Division, for making the counts of healthy and smutted heads in the test at Aberdeen, Idaho, in 1930.

[2] United States Department of Agriculture. Bureau of Plant Industry. The following mimeographed material from Plant Disease Bulletin (or Reporter):

Estimate of crop losses due to plant diseases. 1917. Plant Disease Bul. **2**: 1–18. 1918.

Crop losses from plant diseases. 1918. Sup. 6: 186–213. 1919.

Crop losses from plant diseases in the United States in 1919. Sup. 12: 307–332. 1920.

Crop losses from plant diseases in the United States in 1920. Sup. 18: 317–338. 1921.

Crop losses from plant diseases in the United States in 1921. Sup. 24: 489–510. 1922.

Crop losses from plant diseases in the United States in 1922. Sup. 30: 462–490. 1923.

Crop losses from plant diseases in the United States in 1923. Sup. 36: 318–348. 1924.

Crop losses from plant diseases in the United States in 1924. Sup. 43: 381–410. 1925.

Crops losses from plant diseases in the United States in 1925. Sup. 49: 382–412. 1926.

Crop losses from plant diseases in the United States in 1926. Sup. 56: 394–423. 1927.

Crop losses from plant diseases in the United States in 1927. Sup. 64: 370–399. 1928.

The formaldehyde (liquid) treatment has been recommended for the control of oat smut since 1897 (1). The continued heavy loss from smut in oats would seem to indicate, however, that the treatment is not very extensively used. This seems due chiefly to two causes: (1) The reluctance of many growers to use any form of wet treatment for grains and (2) the not uncommon reports of injury to the germination of seed oats resulting from treatment with formaldehyde.

In the past few years an increasing number of American and foreign manufacturers have marketed various chemical dusts prepared especially for treating seed oats for smut control or for treating diseased seed of various crops. In 1928, 1930, and 1931 the writer tested at the Arlington Experiment Farm, Rosslyn, Virginia, or at the Aberdeen Substation, Aberdeen, Idaho, a total of 21 dusts on 20 lots of oats, naturally inoculated either with loose or covered smut or both, obtained from heavily smutted fields in various parts of the United States. In 1930 and 1931 the formaldehyde (liquid) treatment also was included in the tests. Some of the dusts produced excellent control of both smuts without injury to seed germination. The results of the tests follow.

EXPERIMENTAL WORK

Materials, Methods, and Results

1928 experiments. The seed lots used in these experiments were from the 1927 crop. Lot 1 was a mixture mostly of Silvermine from New Jersey; lot 2 was a mixture of Silvermine, Fulghum, and an unknown variety from North Carolina; and lot 3 was Silvermine from Ohio.

The crops that produced the seed lots used in the experiment contained relatively high percentages of the smutted heads that served as the source of inoculum for producing infection under natural conditions. None of the seed lots were artificially smutted.[3]

The chemical dusts were applied at the rate of 4 oz. to the bushel of seed, on April 3, 1928. Lots of 96 gm. of seed and 750 mg. of dust were placed in 1-lb. tins with screw caps. The latter were turned end over end for 5 minutes in a motor-driven box (described and illustrated by Leukel (13)), making 32 revolutions per minute. Ninety-six-gram (check) lots, to which no chemical dust was added, also were similarly agitated. Through the use

[3] The artificial method of inoculation in which dry spores are applied to the exterior surfaces of the glumes has been shown by Reed and Faris (17), Kolk (10), and others to be very effective in producing infection under appropriate seed-bed conditions. However, in view of the work of Zade (22, 23) and his coworkers in Germany and of Gage (5) in the United States, showing the importance of intraglume inoculum in nature, it seemed expedient to use only seed that was inoculated under natural conditions in the floral stage.

of this method the dusts were uniformly applied, and treated and nontreated seed were handled alike, except as to the dust application. In applying the dusts to such small quantities of seed relatively large portions of the finely ground chemicals adhered to the inner surfaces of the containers used in treatment. For this reason the dusts were applied at the 4-oz. rate per bushel instead of the 3-oz. rate usually recommended. Immediately after treatment of the seed with the different dusts, except the sulphurs, on April 3, the caps of the treating tins were removed and the treated seed was exposed to the outside air. The following day 1 lot of 250 seeds of each treated unit and 2 lots of 250 seeds of each nontreated unit were counted and packeted. The lots were sown in rod rows at the Aberdeen Substation, Aberdeen, Idaho, on April 11. On April 15, seed of lot No. 1 was treated with the sulphur dusts shown in table 2, following the method used in the application of the other dusts. The following day 12-gm. samples of all of the dusted and nondusted units of lot No. 1 were packeted. The seed was sown in rod rows at the Arlington Experiment Farm, Rosslyn, Virginia, on April 20. The results at Aberdeen and at Arlington Farm are shown in tables 1 and 2, respectively.

The combined data in tables 1 and 2 show that Ceresan (especially Ceresan K–1–C) was the only dust effective in smut control under the conditions of the experiment in 1928 and that none of the dusts reduced seedling emergence.

1930 experiments. In 1930, 10 lots of seed from heavily smutted fields in different States were treated each with 10 different chemical dusts and the formaldehyde liquid dip.

Seed lot 4 was Green Russian, from Iowa, from the 1928 crop. Lot 5 was a mixture, mostly Green Russian, from New Jersey, from the 1927 crop; seed lots 6, 7, and 8 were Kanota, from the 1928 crop. Lots 6 and 8 came from Kansas and lot 7, from Wisconsin. Lots 9 to 13 were from the 1929 crop, lot 9 being Fulghum from Arkansas, lots 10, 11, and 12, Burt, 60-Day, and Iowa 103, respectively, from Illinois, and lot 13 was Frazier, from New Jersey.

The dusts were applied on March 14. The technique and rate of application used in 1928 were again employed. Immediately after treatment the lids of the treating tins were removed, thus exposing the treated seed to the outside air, except that the tin containing seed treated with Smuttox was kept closed until the following day[4] and the tin containing seed treated with Kantsmut dust was kept closed for 3 days after treatment.[5] The

[4] Manufacturers' instructions are to keep treated seed sacked and allow same to stand at least 3 hours, or, preferably, overnight, before sowing.

[5] Manufacturers' instructions are to keep treated seed covered 2 to 5 days after treatment.

TABLE 1.—*Seedling emergence and smuttiness in 3 lots of oats grown in 1928 at Aberdeen, Idaho, from naturally inoculated seed. Seed nontreated or treated with 1 of 6 chemical dusts and sown in rod rows*

Seed treatment	Seed lot 1		Seed lot 2		Seed lot 3		Seed lots 1, 2, and 3				
	Number of heads in rod row	Number of smutty heads	Number of heads in rod row	Number of smutty heads	Number of heads in rod row	Number of smutty heads	Number of heads	Number of smutty heads	Percentage of smutty heads	Number of seedlings emerged from 750 seeds (250 seeds from each of the 3 lots)	Percentage of emergence
Abavit B	458	131	612	34	375	42	1445	207	14.3	620	82.7
Tillantin höchst	414	33	602	3	381	21	1397	57	4.1	634	84.5
Tutan	450	161	618	48	385	28	1453	237	16.3	645	86.0
Nontreated	452	173	553	56	448	88	1453	317	21.8	637	85.5
Ceresan (K–1–C)	423	6	576	2	477	0	1476	8	0.5	641	85.5
Ceresan (K–1–D)	447	15	522	0	386	0	1355	15	1.1	632	84.3
D. D. D. 68	538	141	560	38	395	26	1493	205	13.7	641	85.5

TABLE 2.—*Smuttiness in oats grown in 1928 at Arlington Experiment Farm, Rosslyn, Virginia, from naturally inoculated seed.*[a] *Seed nontreated or treated with each of 11 chemical dusts*

Seed treatment	Number of heads in rod row	Number of smutty heads	Percentage of smutty heads
Abavit B	442	139	31.4
Tillantin höchst	397	46	11.6
Tutan	306	57	18.6
Anchor Sulfur	357	86	24.1
Nontreated	371	65	17.5
Ceresan (K–1–C)	462	0	0.0
Ceresan (K–1–D)	480	9	1.9
D.D.D. 68	449	47	10.5
Nontreated	431	68	15.8
Niagara Sulfur No. 76	456	44	9.6
" " " 77	482	40	8.3
" " " 78	482	67	13.9
" " " 79	554	84	15.2

[a] Lot No. 1.

formaldehyde dip was applied March 15. The oats contained in half-filled cheesecloth bags were immersed for 10 minutes in a 1 to 320 solution of formaldehyde and water. The sacks then were left to drain for 1 hour, piled together, covered with sacks, and left overnight. The following morning the treated seed was spread out in thin layers and left 2 days to become thoroughly dry and aerated.

Following application of the different treatments as noted above, 2 sets of 250 seeds of each treated and nontreated unit were packeted and sown in rod rows at Arlington Experiment Farm, the first set on March 19, the second on April 14. Following treatment 2 sets, consisting of 12-gm. samples each, also were prepared. These were sown at the Aberdeen Substation, Aberdeen, Idaho, the first set on April 15, the second on May 12. Similar results were obtained from the early and later sowings at Arlington Experiment Farm, and for convenience, the data have been combined in table 3. At Aberdeen a higher percentage of smutty heads appeared in the earlier sowing, as shown in table 4.

The data in tables 3 and 4 show that smut was entirely eliminated in the early and later sowings at both Aberdeen and Arlington Experiment Farm, when the plants were grown from seed treated with the formaldehyde dip or the dusts Dubay 655 and Dubay 665. Excellent control also was obtained from seed treatment with Kantsmut dust, Corona Oat Dust, and Smuttox dust. Ceresan was fairly effective at Arlington Experiment

TABLE 3.—*Seedling emergence and smuttiness in 10 lots of oats grown in 1930 at Arlington Experiment Farm, Rosslyn, Virginia, from naturally inoculated seed. Seed nontreated or treated with formaldehyde (liquid) or with 1 of 10 chemical dusts*

Seed treatment	Number of smutty heads in 600 heads of each seed lot. (300 consecutive heads in a rod row from each of 2 series)										Number of smutty heads in 6,000 heads (600 heads from each of the 10 lots)	Percentage smutty heads	Number of seedlings from 1,000 seeds (100 seeds from each of the 10 lots)	Percentage of emergence
	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9	Lot 10	Lot 11	Lot 12	Lot 13				
Acco dust	9	47	66	28	78	27	10	16	2	57	340	5.67	918	91.8
Ansbacher grain dust	0	3	0	0	1	1	1	1	2	4	13	0.22	908	90.8
Ceresan dust	0	0	0	0	0	0	0	0	0	1	1	0.02	907	90.7
Dubay dust No. 655	0	0	0	0	0	0	0	0	0	0	0	0	905	90.5
Dubay dust No. 665	0	0	0	0	0	0	0	0	0	0	0	0	913	91.3
Nontreated	8	28	29	28	28	43	19	12	2	70	267	4.45	918	91.8
Formaldehyde dip	0	0	0	0	0	0	0	0	0	0	0	0	896	89.6
Kantsmut dust	0	0	0	0	0	0	0	0	0	0	0	0	922	92.2
Oat Dust (Corona)	0	0	0	0	0	2	0	0	0	0	2	0.03	934	93.4
Smuttox dust	0	0	0	0	0	0	0	1	0	0	1	0.02	892	89.2
Sterocide dust	5	21	37	11	28	42	19	13	2	44	222	3.70	925	92.5
WaWa dust	0	0	1	0	0	0	1	0	0	4	6	0.10	866	86.6

TABLE 4.—*Smuttiness in 10 lots of oats grown in 1930 at Aberdeen, Idaho, from naturally inoculated seed. Seed nontreated or treated with formaldehyde (liquid) or with 1 of 10 chemical dusts*

Seed treatment	Number of smutty heads in row rows containing approximately 650 heads per row																			
	First sowing										Second sowing									
	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9	Lot 10	Lot 11	Lot 12	Lot 13	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9	Lot 10	Lot 11	Lot 12	Lot 13
Acco dust	45	48	71	155	97	83	69	81	24	185	45	66	27	101	45	22	28	18	4	51
Ansbacher grain dust	0	5	21	5	6	39	6	0	0	96	0	11	2	4	2	2	0	0	0	1
Ceresan dust	0	0	1	1	2	5	0	0	0	18	0	0	0	0	0	0	0	0	0	2
Dubay dust No. 655	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dubay dust No. 665	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nontreated	29	16	43	70	80	71	28	24	6	157	6	19	2	37	10	8	2	0	0	15
Formaldehyde dip	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oat Dust (Corona)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kantsmut dust	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Smuttox dust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sterocide dust	6	27	74	43	86	100	36	28	8	152	6	31	6	19	12	17	11	6	3	17
WaWa dust	0	9	16	1	23	12	6	5	6	34	0	5	0	0	2	0	0	0	0	1

Farm and in the second sowing at Aberdeen but less effective in the first sowing at Aberdeen. WaWa dust and Ansbacher grain dust did not reduce the smut sufficiently to merit further consideration. Sterocide had little influence on the occurrence of smut. It is interesting to note that plants from seed treated with Acco dust produced more smut than those from nontreated seed in 5 of the 10 lots at Arlington Experiment Farm and in all of the lots at Aberdeen, Idaho. None of the treatments appreciably reduced seedling emergence. (Table 3.)

1931 experiment. The experiment was concluded in 1931. In this year 3 of the lots (Nos. 9, 10, and 11) used in 1930 and 7 new lots from very smutty plots or fields in different States were each treated with the formaldehyde liquid dip and the dusts that produced satisfactory control the previous year, namely: Ceresan, Dubay No. 655, Dubay No. 665, Kantsmut, Oat Dust, and Smuttox.

Seed lots Nos. 9, 10, and 11 were from the 1929 crop, and lots 14 to 20 were from the 1930 crop. Lot 9 was Fulghum from Arkansas, and lots 10 and 11 were Burt and 60-Day, respectively, from Illinois. Lot 14 was Kanota, lot 15, Green Russian, lot 16, Frazier, and lot 19 was Fulghum, all from New Jersey. Lots 17 and 18 were unknown varieties from the same State. Lot 20 was Fulghum from South Carolina.

The dusts were applied March 3, 1931. The technique and rate of application and the post-treatment handling of the treated seed closely followed those of the previous years. The seed treated with Smuttox and Kantsmut was again kept confined in the closed tins for 1 and 3 days, respectively, after treatment, in accordance with manufacturers' instructions on the label of the product. The formaldehyde dip also was applied according to the procedure in 1930. Twelve-gram samples of each treated and nontreated unit were sown in rod rows in triplicate series at the Arlington Experiment Farm, on April 9. The following day 100 seeds of each treated and nontreated unit were sown in soil in a greenhouse bench to study further the effects of the treatments on seedling emergence. The results of the experiment are presented in table 5.

The data in table 5 show that all of the treatments produced excellent control of both loose and covered smuts, particularly the formaldehyde (liquid) dip. The latter reduced emergence of seedlings from 93.3 per cent to 88.8 per cent, but with this exception none of the treatments reduced emergence below 90 per cent.

DISCUSSION

Under the conditions of the present experiments, the following treatments applied to naturally inoculated seed oats eliminated smut or reduced it to 1 per cent of smutty heads or less in plants grown from the treated

TABLE 5.—*Seedling emergence and smuttiness in 10 lots of oats grown in 1931 at Arlington Experiment Farm, Rosslyn, Virginia, from naturally inoculated seed. Seed nontreated or treated with formaldehyde (liquid) or with 1 of 6 chemical dusts*

Seed treatment	Number of smutty heads in 900 heads of each seed lot. (300 consecutive heads in a rod row from each of 3 series)										Number of smutty heads in 9,000 heads. (900 heads from each of the 10 lots)	Percentage of smutty heads	Number of seedlings from 1,000 seeds. (100 seeds from each of the 10 lots)	Percentage of emergence
	Lot 9	Lot 10	Lot 11	Lot 14	Lot 15	Lot 16	Lot 17	Lot 18	Lot 19	Lot 20				
Ceresan dust	0	0	0	0	0	0	0	0	2	0	2	0.022	929	92.9
Dubay dust No. 655	0	0	0	0	0	1	0	0	0	0	1	0.011	934	93.4
Dubay dust No. 665	0	0	0	0	0	0	0	0	1	0	1	0.011	933	93.3
Nontreated[a]	158	114	128	310	103	332	152	221	237	231	1986	22.066	933	93.3
Formaldehyde dip	0	0	0	0	0	0	0	0	0	0	0	0.00	888	88.8
Kantsmut dust	1	0	2	3	0	1	0	0	7	2	16	0.177	910	91.0
Oat Dust (Corona)	0	0	0	2	1	2	0	0	5	2	12	0.133	909	90.9
Smuttox dust	1	1	0	9	0	6	0	1	0	2	20	0.222	918	91.8

[a] The occurrence of either loose or covered smut in plants from nontreated seed of the 10 lots was as follows: Lots 9, 10, 11, 14, 16, 19, and 20—apparently all heads loose smut. Lot 15—loose and covered smut heads occurring in the ratio approximately of 1 to 2, respectively. Lots 17 and 18—covered smut predominant; loose smut present only in a few heads.

seed: The formaldehyde (liquid) dip and the dusts Dubay No. 655, Dubay No. 665, Smuttox, Kantsmut, and Corona Oat Dust. Ceresan dust also produced excellent control except that in one case plants from treated seed contained 2.8 per cent smutty heads. The formaldehyde (liquid) dip caused a reduction in seedling emergence from 93.3 per cent to 88.8 per cent in 1931; otherwise, none of the treatments appreciably affected germination.

Some of the treatments listed above have been studied previously with regard to effectiveness in smut control and influence on seed vitality and on yield of plants from treated seed. The effectiveness of the formaldehyde (liquid) treatment in the control of smut in oats when applied as a spray, sprinkle, or dip has been repeatedly shown since Bolley's introduction of formaldehyde as a fungicide in 1897 (1) and is unquestioned. A survey of some of the reports with regard to the effect of the formaldehyde treatment on germination shows that in many cases results similar to those obtained by the writer have been obtained, *i.e.*, little or no injury to germination was brought about through seed treatment. However, reports of serious impairment of seed vitality not infrequently have been obtained (4, 11, 12, 14, 15, 20, 21). Sayre and Thomas (19) also state that the effectiveness of the formaldehyde (liquid) treatment in smut control is unquestioned but, in Ohio, "there have been many instances of serious injury to germination." Hurd (8) has well demonstrated the importance of post-treatment conditions of humidity in relation to injury to seed wheat treated with formaldehyde. It seems possible that a similar relation may hold true for formaldehyde-treated oats.

Previous reports concerning the new Dubay dusts included in the writer's tests apparently have not been made. Ethyl mercury phosphate is the active ingredient. The dusts Smuttox, Kantsmut and Corona Oat Dust are similar in composition and contain 4, 4, and 5 per cent formaldehyde, respectively. The formaldehyde-dust treatment for control of smut in oats, invented by Sayre and Thomas (19) of the Ohio Agricultural Experiment Station and introduced in 1927, has been extensively tested in recent years with uniformly good results. Sayre and Thomas (19) and Sayre (18) report excellent control without seed injury in both experimental tests and tests by growers in many parts of Ohio. Similar results have been obtained by other investigators in different parts of the United States and Canada in tests of the commercial formaldehyde dusts, especially Smuttox (2, 3, 6, 7, 9, 11). Ceresan dust also has been extensively tested in recent years and has given satisfactory results (2, 3, 6, 7, 9, 11).

Dusts of different chemical composition are now available for controlling the smuts and other small grain parasites amenable to control through surface disinfection of the seed. In the light of recent progress in the develop-

ment of seed dusts it seems reasonable to suppose that single dusts may be evolved that will replace the confusing array of wet, semidry, and dry treatments with different chemicals, different methods of application, and different post-treatment handlings now recommended. In fact, Ceresan dust already has been shown to be effective in the control of most of the pathogens in this class. Recent improvements in the manufacture of certain dusts indicate that one of the most serious objections to the dusts, the relatively high cost, may be eliminated.

Doubtless a universal dry treatment that might prove to be inexpensive, easily applied, effective in smut control, and noninjurious to seed germination and to man would tend to popularize the treatment of seed oats and the seed of other small grain crops.

SUMMARY

1. Tests of dust fungicides on oats, both at Arlington Experiment Farm, Rosslyn, Virginia, and the Aberdeen Substation, Aberdeen, Idaho, in 1928 and in 1930 and at Arlington Experiment Farm in 1931 included 21 chemical dusts and the formaldehyde (liquid) dip on 20 lots of naturally inoculated seed. The content of loose or covered smut or both in plants from nontreated seed of the different lots generally ran high. The dusts were applied at the rate of 3 oz. or slightly more per bushel. The formaldehyde dip was applied by immersing seed for 10 minutes in a 1–320 formaldehyde-water solution, followed by draining off the excess liquid, covering seed overnight, and aeration for several days after treatment.

2. With regard to smut control, the different seed treatments behaved as follows:

A. The formaldehyde (liquid) dip used in 1930 and 1931 proved the most effective. It completely eliminated smut in every seed lot.

B. The Dubay dusts No. 655 and No. 665 used in 1930 and 1931 reduced smut to zero in 1930 and to 0.01 per cent in 1931. In the 2-year test the plants from seed treated with each of the dusts produced approximately 28,000 heads, all smut-free except one. The plants from nontreated seed in 1930 and 1931 produced 2,876 smutty heads in approximately 28,000.

C. The formaldehyde dusts, Smuttox, Kantsmut, and Corona Oat Dust, tested in 1930 and 1931, were next in effectiveness, reducing smut to 1 per cent or less in every seed lot and to zero in most of the lots.

D. Ceresan, tested in 1930 and 1931, produced excellent control except that in 1 lot in the first sowing at Aberdeen, Idaho, in 1930, plants from Ceresan-treated seed produced 18 smut heads in 650 (2.8 per cent). Plants from nontreated seed of this lot produced 24.2 per cent smutty heads. With this exception, Ceresan eliminated smut or reduced it to a trace.

E. K–1–C, tested in 1928, produced fairly satisfactory control. K–1–D, also tested in 1928, was less effective. These dusts, the experi-

mental forerunners of Ceresan, are similar to the latter but contain less of the toxic ingredient (ethyl mercury chloride).

F. Ansbacher Grain Dust and Wa Wa Dust, tested in 1930, were effective in the sowing at Arlington Experiment Farm and in the second sowing at Aberdeen, Idaho, but these dusts produced unsatisfactory control in the first sowing at Aberdeen.

G. The following dusts proved unsatisfactory: Abavit B, Acco, Anchor Sulfur, D.D.D. No. 68, Niagara sulfurs Nos. 76, 77, 78, and 79, Sterocide, Tillantin Höchst, and Tutan. Plants from seed treated with Acco dust, in 1930, produced more smut than those from nontreated seed in 5 of the 10 lots grown at Arlington Experiment Farm and in all of the 10 lots in both sowings at Aberdeen, Idaho.

3. With regard to the effects of the various treatments on seedling emergence, the formaldehyde (liquid) dip reduced emergence from 93.3 per cent to 88.8 per cent in 1931. With this exception none of the effective treatments produced appreciable reduction.

4. Facts showing the importance of oat-smut control are: (1) the appearance in recent years of new physiologic forms of the loose- and covered-smut fungi that attack important varieties hitherto highly resistant or immune and (2) the estimated annual loss from oat smut approximating 50,000,000 bushels.

LITERATURE CITED

1. BOLLEY, H. L. New studies upon the smut of wheat, oats and barley, with a résumé of treatment experiments for the last three years. N. Dak. Agr. Exp. Sta. Bul. 27. 1897.
2. CHURCHILL, B. R. Investigations with oat varieties and diseases in the Upper Peninsula. Mich. Agr. Exp. Sta. Spec. Bul. 213. 1931.
3. CONNERS, I. L. Smut investigations. Rpt. Canada Exp. Farms (Rpt. Dom. Bot.) **1929**: 109–116. 1931.
4. CRANEFIELD, F. The influence of formalin on the germination of oats. Ann. Rpt. Wis. Agr. Exp. Sta. **18** (1900–1901): 327–335. 1901.
5. GAGE, GEORGE RAYMOND. Studies of the life history of *Ustilago avenae* (Pers.) Jensen and of *Ustilago levis* (Kell. & Swing.) Magn. N. Y. (Cornell) Agr. Exp. Sta. Mem. 109. 1927.
6. HANNA, W. F., and W. POPP. Researches on smut diseases. Rpt. Canada Exp. Farms (Rpt. Dom. Bot.) **1930**: 68–75. 1931.
7. HORSFALL, JAMES G. Dusting seed for oat smuts. Phytopath. **19**: 173–175. 1929.
8. HURD, ANNIE MAY. Injury to seed wheat resulting from drying after disinfection with formaldehyde. Jour. Agr. Res. **20**: 209–244. 1920.
9. KOEHLER, BENJ. Effect of time and rate of application of seed disinfectants on oats and wheat. (Abst.) Phytopath. **21**: 127. 1931.
10. KOLK, LAURA ALMA. Relation of host and pathogen in the oat smut, *Ustilago avenae*. Bul. Torr. Bot. Club **57**: 443–507. 1930.
11. LEHMAN, S. G., and G. W. FANT. Control of oat smut by seed treatment. N. C. Agr. Exp. Sta. Bul. 268. 1929.

12. LEUKEL, R. W. Further experiments on the control of bunt of wheat and the smuts of barley and oats. Phytopath. **16**: 347–351. 1926.

13. ————. Seed treatment for controlling covered smut of barley. U. S. Dept. Agr. Tech. Bul. 207. 1930.

14. MARTIN, WM. H. Oats smut control studies. Ann. Rpt. N. J. Agr. Exp. Sta. **46**: 457–460. 1926.

15. MILLER, W. B. Smut in oats. Dry pickling effective. Jour. Dept. Agr. Victoria **29**: 86–89. 1931.

16. REED, GEORGE M. New physiologic races of the oat smuts. Bul. Torrey Bot. Club **56**: 449–470. 1929.

17. ————, and J. A. FARIS. Influence of environal factors on the infection of sorghums and oats by smuts II. Experiments with covered smut of oats and general considerations. Amer. Jour. Bot. **11**: 579–599. 1924.

18. SAYRE, J. D. Formaldehyde dust for the control of oat smut. Bimonth. Bul. Ohio Agr. Exp. Sta. **14**: 9–11. 1929.

19. ————, and R. C. THOMAS. Formaldehyde and iodine dusts for the control of oat smut. Bimonth. Bul. Ohio Agr. Exp. Sta. **13**: 19–21. 1928.

20. STEWART, ROBERT, and J. STEPHENS. The effect of formalin on the vitality of seed grain. Utah Agr. Exp. Sta. Bul. 108: 145–156. 1910.

21. TISDALE, W. H., J. W. TAYLOR, R. W. LEUKEL, and MARION A. GRIFFITHS. New seed disinfectants for the control of bunt of wheat and the smuts of oats and barley. Phytopath. **15**: 651–676. 1925.

22. ZADE, A. Experimentelle Untersuchungen über die Infektion des Hafers durch den Haferflugbrand (*Ustilago avenae* Jens.) Fühling's Landw. Ztg. 71: 393–406. 1922.

23. ————. Neuere Untersuchungen über die Lebensweise und Bekämpfung des Haferflugbrandes (*Ustilago avenae* [Pers.] Jens.) Angew. Bot. **6**: 113–125. 1924.

RESISTANCE OF MONOCOTYLEDONS TO PHYMATOTRICHUM ROOT ROT[1]

J. J. Taubenhaus and Walter N. Ezekiel

Phymatotrichum root rot attacks a considerable proportion of the cultivated dicotyledonous plants (6), but it has been generally assumed, even by growers, that monocotyledonous plants, such as corn, sorghum, Sudan grass, and grass and grain crops in general, are resistant to the disease. In the first scientific description of the disease by Pammel (4), it was noted that: "So far as is known the fibrous-rooted plants, such as corn, oats and wheat, are exempt from the disease, and where practicable these should follow cotton." In field studies of graminaceous crops, over a period of 14 years, in all parts of Texas, the writers have not found a single monocotyledonous plant that showed lesions of Phymatotrichum root rot or that had succumbed to the disease. Graminaceous crops have therefore been recommended (11, 10) as nonsusceptible crops to be used in rotations where root rot occurs.

Recently, however, King and Loomis (3) have emphasized that the Phymatotrichum fungus will grow in artificial cultures on graminaceous roots, and they report also having found Phymatotrichum strands occurring naturally on the roots of date palms, Johnson grass, and Bermuda grass. They considered this as evidence that monocotyledonous plants are hosts to root rot and suggested that plants of this sort may act as carriers of the disease. It has therefore appeared necessary to study further the question of whether monocotyledonous plants may be hosts to this disease. This is of particular importance, since, unless monocotyledonous plants are resistant to Phymatotrichum root rot, there are practically no crops that can be recommended for rotations for the control of the disease.

PRELIMINARY INOCULATIONS OF SORGHUM PLANTS

In the summer of 1928, sorghum and cotton plants were grown in separate containers filled with Lufkin fine sandy-loam-soil material to which was added 1 per cent of ground limestone to make the soil favorable for root rot. On September 8 and again on October 9 the plants in 4, each, of the cotton and sorghum containers were copiously inoculated with Phymatotrichum root rot. The method of inoculation as described in more detail elsewhere (5) consisted of placing freshly infected cotton roots in holes next to the plants to be inoculated. Two containers, each, of cotton and sorghum plants were left noninoculated as checks. Within 20 days, the inoculated

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cotton plants had succumbed to typical Phymatotrichum root rot, while the noninoculated cotton plants remained normal throughout the season. Neither the inoculated nor the noninoculated sorghum plants showed any evidence of infection but remained normal and continued to grow. On November 8, 1928, the roots of all the inoculated and noninoculated cotton and sorghum plants were washed out from the soil and carefully examined for root decay and for the presence of Phymatotrichum strands. Roots of the inoculated cotton plants were found to be decayed, with typical symptoms of root rot and numerous Phymatotrichum strands that clung to the infected roots and had not washed off in washing the soil from the roots. On the other hand, the roots of the noninoculated cotton plants, as well as the roots of both the inoculated and noninoculated sorghum plants, showed no evidence whatever of root decay or Phymatotrichum strands.

On the roots of both the check and the inoculated sorghum plants there were distinct, dark lesions, penetrating deeply into the roots, which might have been considered as possibly caused by Phymatotrichum root rot. Very exhaustive microscopic study of these sorghum root lesions failed to reveal any evidence of Phymatotrichum growth. A number of Petri-dish cultures were made from these lesions as well as from lesions on cotton roots that had been inoculated with Phymatotrichum root rot. Typical Phymatotrichum growth was readily recovered from the cotton-root lesions, while the sorghum root lesions invariably yielded a species of Fusarium and a Rhizoctonia, with no Phymatotrichum from either inoculated or noninoculated sorghum plants. These preliminary results suggested strongly that sorghum, a monocotyledonous plant, is not susceptible to root rot.

EXPERIMENTS IN 1930

More recent experiments have included inoculations of a number of plants growing in field plots (8, 9); inoculations of potted plants in the laboratory; and also inoculations of fleshy storage bodies in moist chambers in the laboratory.

Inoculations in field plots. It appeared desirable to repeat the preliminary work reported above more extensively, using a larger number of monocotyledonous plants. Early in the spring of 1930 some field plots were prepared in the senior writer's home garden at College Station. The soil in this garden is a typical Lufkin fine sandy loam with a pH of 7.0–7.6 and thus well within the range found favorable for root rot (1). However, to insure conditions highly favorable for root rot, finely ground limestone at the rate of 1 ton per acre was incorporated into the soil. It is to be noted that susceptible crops had been grown in this garden previously for at least 10 years without any evidence of root rot; artificial inoculations were therefore the sole source of infection in these tests, without any variability from

such local differences in prevalence of the disease as may be expected when natural infection is depended on.

The land available was divided into 5 plots, each about 12 x 36 ft., and planted to the monocotyledons. These presumably resistant plants were interplanted with carrots, cotton, or okra, which are highly susceptible to root rot. The monocotyledonous plants included corn, *Zea mays*; cannas, *Canna indica*; Caladium, *Colocasia illustris*; Iris, *Iris* sp.; tuberose, *Polianthes tuberosa*; gladiolus, *Gladiolus* sp.; tiger-lily, *Lilium tigrinum*; pink zephyr lily, *Zephyranthes* (*Atamosco*) *rosea*; Tritonia, *Tritonia* (*Montbretia*) sp.; day lily, *Hemerocallis* sp.; nut grass, *Cyperus rotundus* L.; hedge bamboo *Bambusa nana*; evergreen shallot, *Allium ascalonicum*; and 3-year-old date palms, *Phoenix dactylifera*. Parallel plantings of corn and cotton were made at intervals throughout the season (Table 2). When the plants were fully grown, the monocotyledons as well as the susceptible dicotyledons were inoculated periodically with fresh inoculum of naturally infected carrot or cotton roots. Detailed results are given in tables 1 and 2, except for the date palms, which showed no aboveground symptoms of

TABLE 1.– *Results of 1930 field-plot inoculations with Phymatotrichum root rot, including miscellaneous monocotyledonous plants with carrot and okra plants as checks* [*Planted Feb. 18–March 3, 1930, except nut grass, which was present as a weed*]

Plants	Dates of inoculation	Results		
		Date of observation	Total number of plants	Percentage of plants infected with Phymatotrichum root rot
Gladiolus	April 26, May 12, July 7	Aug. 2	460	0[a]
Hedge bamboo	April 26, May 12, July 7 Aug. 10, Sept. 11	Nov. 29	12	0
Iris	"	"	12	0
Shallot	"	"	150	0
Carrot	May 12, July 7	Aug. 2	100	97
Okra	May 12, June 15, July 7	"	100	100
Caladium	May 12, July 7, Aug 10	Aug. 27	50	0[b]
Canna	May 12, July 7, Aug. 10, Sept. 11	Oct. 7	50	0
Day lily	"	Nov. 10	50	0
Mexican tuberose	"	"	50	0
Tritonia	"	"	50	0
Tiger lily	"	"	50	0
Zephyr lily, pink	"	"	50	0
Nut grass	Aug. 2, Sept. 5, Sept. 20	Nov. 29	100	0

[a] Some of mother bulbs and lateral roots infected with Pythium dry rot.

[b] Some of Caladium roots showed lesions caused by *Sclerotium rolfsii*.

TABLE 2.—*Field-plot inoculations with Phymatotrichum root rot in 1930 of cotton and corn planted periodically*

Dates of planting	Plant	Date of inoculation	Results		
			Date of observation	Total number of plants	Percentage of plants with Phymatotrichum root rot
May 5	Corn	June 20, July 7, Aug. 2	Nov. 11	240	0
	Cotton	"	"	240	100
June 5	Corn	Aug. 2, Sept. 5, Sept. 20	Nov. 29	200	0
	Cotton	"	"	200	100
August 5	Corn	Sept. 5, Sept. 20	Oct. 9	240	0
	Cotton	"	"	240	96
Sept. 8	Corn	Oct. 11, Oct. 28	Nov. 29	140	0
	Cotton	"	"	140	79
	Cotton	Check, noninoculated	"	100	0

root rot and were left in the ground for further testing. None of the roots of the monocotyledonous plants tested showed the least evidence of Phymatotrichum root rot. On the other hand, high percentages of the inoculated carrot, okra, and cotton plants succumbed to typical Phymatotrichum root rot (Fig. 1, A, B, and D). These susceptible, dicotyledonous plants had been interplanted between the monocotyledons throughout all 5 plots, and the uniform infection of these dicotyledonous plants proved that conditions throughout the entire area had been favorable for the development of the disease. The absence of root rot on the monocotyledons was thus strong evidence of the resistance of these plants to the disease.

Lesions on graminaceous roots. When the roots of the dicotyledonous and monocotyledonous plants were dug out at the end of the season typical Phymatotrichum root-rot lesions were found on the roots of the dicotyledonous plants, but there were also dark lesions on the roots and rootlets of inoculated and also of noninoculated corn plants. These lesions appeared similar to those found previously on sorghum roots. Many corn roots showing such lesions, as well as the roots of dicotyledonous plants infected with typical Phymatotrichum root rot, were cultured by the soil-culture method. This method, described elsewhere (7), consists of placing roots in jars filled with moist soil. The writers used quart Mason jars of Houston clay soil with 25 per cent moisture on a dry-weight basis. With roots affected by Phymatotrichum root rot, the strands of the fungus grown out

FIG. 1. Inoculation experiments with Phymatotrichum root rot. A and D. Cotton and corn plants, interplanted in same row in A and in alternate rows in D. All inoculated. Cotton plants dead or dying from root rot and corn plants normal. B. Canna and okra planted alternately in the same row and inoculated. Okra plants dead from root rot and canna plants normal. C. Lesions on corn root, as found in root-rot and root-rot-free areas and proved distinct from Phymatotrichum root rot.

and are readily visible along the sides of the glass. Such strands frequently also produce an abundance of Phymatotrichum sclerotia. This method has made it possible to determine whether root lesions were the result of Phymatotrichum infection, thus supplementing standard methods of isolation and pure culture.

The results of these cultures are summarized in table 3. No Phymatotrichum growth appeared in the soil cultures from either the inoculated or the noninoculated corn roots. However, copious Phymatotrichum strand growth and sclerotia were secured from the inoculated cotton roots. In cultures in which Phymatotrichum-infected cotton roots were mixed with the corn roots, Phymatotrichum growth was obtained only from the infected cotton roots and not from the corn roots. This was proved by breaking open the glass containers and carefully dissecting the soil to determine from which of the roots the Phymatotrichum strands were coming.

In addition to the soil cultures mentioned, series of test-tube cultures also were made from the Phymatotrichum-infected cotton roots and from many of the lesions of the corn roots growing in the same plots. Pieces of root tissue sterilized ½ minute in 1–2000 mercuric chloride in 25 per cent alcohol and rinsed in sterilized water were inserted in slants of agar. Typical Phymatotrichum root-rot growth was always recovered from the Phymatotrichum-infected cotton roots but never from the check, noninoculated cotton roots, nor the lesions on the corn roots. Instead, colonies of Fusarium, Rhizoctonia, and several other undetermined organisms grew from the corn-root lesions. From this it seems evident that the lesions found on the roots of inoculated corn plants were not caused by Phymatotrichum root rot.

Extensive field studies were made in 1928, 1929, 1930, and 1931 of corn, sorghum, and other graminaceous plants found growing in different sections of Texas, not only in root-rot-infected areas but also in parts of east Texas and on individual farms in Brazos County where root rot has not been known to occur. Whether secured from root-rot or root-rot-free areas, the roots of the corn, sorghum, nut grass, and Johnson grass frequently showed numerous dark reddish lesions resembling those found on the corn roots from the plots (Fig. 1, C). Many of these lesions were cultured, using the soil-chamber method. As noted in table 3, no Phymatotrichum growth ever appeared from any of the lesions on roots of corn, sorghum, Johnson grass, or nut-grass plants. On the other hand, copious Phymatotrichum strand growth and heavy sclerotia formation were always obtained from cotton roots infected with typical root rot, whether such roots were artificially or naturally infected. These various series agreed in indicating that lesions found on the roots of various graminaceous plants are not caused by Phymatotrichum root rot.

TABLE 3.—*Results of soil-chamber cultures of roots of monocotyledons and dicotyledons exposed to artificial or natural infection with Phymatotrichum root rot*
[*Incubated at 20–34° C., mean = 27.8° C.; final notes taken Jan. 14–29, 1931*]

Material cultured	Date of culturing	Total number of jars	Results: Numbers of jars with Phymatotrichum growth	
			Strands	Sclerotia
From plot experiments:	*1930*			
Corn roots	Sept. 11	83	0	0
	Oct. 9	24	0	0
	Dec. 2	8	0	0
Cotton roots	Sept. 11	14	14	10
	" 12	9	9	9
	Oct. 9	12	12	10
	Dec. 2	5	5	4
	" 13	12	12	10
Cotton and corn roots together in jars	Sept. 12	9	9[a]	7
	Oct. 9	12	12[a]	10
Evergreen shallot	Dec. 9	17	0	0
Caladium	" 13	16	0	0
Nut-grass roots with lesions	" 13	16	0	0
From W. Conrad farm, Brazos County, where Phymatotrichum root rot absent:				
June corn roots with lesions	Dec. 15	48	0	0
Sorghum roots with lesions	"	24	0	0
Nut-grass roots with lesions	"	12	0	0
Cotton roots with Fusarium wilt	"	12	0	0
From Williams farm, Brazos County, where Phymatotrichum root rot abundant:				
June corn roots with lesions	Dec. 16	48	0	0
Sorghum roots with lesions	"	48	0	0
Johnson grass roots with lesions	"	24	0	0
Cotton roots with Phymatotrichum root rot	"	12	12	11
Cotton roots with root rot together in jars with sorghum roots with lesions	"	12	12[a]	12
From Bryan, Texas, root-rot-free area:				
June corn roots with lesions	Dec. 17	48	0	0
June corn roots together in jars with cotton roots from root-rot spots	"	15	15[a]	15

[a] Phymatotrichum strands growing out from cotton roots only.

Soil cultures were made also from the inoculated Caladium, evergreen shallots, cannas, and lilies that were grown in the plot experiments. No Phymatotrichum growth appeared from any of these plants.

Inoculations in the laboratory. In order to test further the resistance of monocotyledons to Phymatotrichum root rot, 2 series of inoculations were carried out in the laboratory. On December 2, 1930, a number of carrots and onions were carefully washed in tap water, dipped in 1–1000 bichloride

of mercury solution, rinsed with sterilized water, and then placed in separate moist chambers. With a flamed scalpel 2 slits were made in each carrot root and onion bulb, and sclerotia from a pure culture were inserted in these slits. Definite Phymatotrichum decay was obtained with 13 of the 16 inoculated carrots, and doubtful infection in 2 others; while not one of the 20 inoculated onion bulbs showed any decay. The check, noninoculated carrots (16 roots) and onions (20 bulbs) also remained normal.

Further inoculations were carried out with Irish potatoes, carrots, onions, hyacinths, cannas, and tuberoses planted in 5-inch pots filled with sifted Houston black clay-soil material. All these plants were inoculated with sclerotia from pure cultures, through scalpel punctures, as in the moist-chamber series above. After 6 weeks, the plants were removed from the soil and examined carefully for any evidence of Phymatotrichum infection. It is to be noted (Table 4) that the Irish potato and the carrot, both

TABLE 4.—*Puncture inoculations, with sclerotia of Phymatotrichum omnivorum, of monocotyledonous and dicotyledonous plants growing in small pots*

[*Inoculated Feb. 26, final results April 7, 1931*]

Plant	Inoculated		Checks, noninoculated	
	Number of pots	Results	Number of pots	Results
Irish potato	2	Typical root-rot decay	2	Normal
Carrot	3	"	2	"
Onion	3	Normal	3	"
Hyacinth, Paper White	4	"	4	"
Canna	4	"	4	"
Tuberose	4	"	4	"

dicotyledonous plants, developed typical Phymatotrichum decay; while the onion, hyacinth, canna, and tuberose, all monocotyledonous plants, remained normal. Thus, even puncture inoculations of these monocotyledonous plants, in soil as well as in moist chambers, have failed to demonstrate any susceptibility to Phymatotrichum root rot under conditions that allowed typical decay of the susceptible, dicotyledonous plants.

DISCUSSION

The resistance of monocotyledonous plants to Phymatotrichum root rot is of great importance in the planning of field control methods. The data presented in the present paper summarize inoculations of 16 kinds of mono-

cotyledonous plants, carried out under both field and laboratory conditions. No infection was obtained with any of these plants, while high percentages of infection were secured with cotton, okra, and carrot plants growing side by side with the monocotyledonous plants.

On 1 or 2 occasions we have found Phymatotrichum strands on roots that may have been Johnson-grass roots, found growing in cotton or alfalfa fields and intimately intermingled with root-rot-infected cotton or alfalfa roots. But, we do not deem this sufficient evidence to consider Johnson grass a host of root rot. It seems more probable that graminaceous roots growing intermingled with the roots of infected susceptible plants may occasionally serve as the physical substratum for a stray strand of the fungus without this being of any pathologic significance. According to the usual conception, susceptibility to a fungus assumes the possibility of definite infection of the plant by the fungus. For a plant, even though resistant to infection, to be a "carrier," should be able to further in some way the survival of the fungus. This term could be applied to a plant that aids in the growth of the fungus or harbors it thereafter over a more extended period of survival than would be possible otherwise but could scarcely be applied to a plant that serves only rarely, if at all, as the completely inert substratum for stray fungus strands. As has been shown above, none of the monocotyledonous plants inoculated have become infected, nor have their roots served as carriers to transfer the fungus to soil cultures or to cultures on ordinary media. The monocotyledonous plants studied have thus far furnished no evidence to justify any change in the assumption that monocotyledonous plants are neither hosts nor carriers of Phymatotrichum root rot. It may be noted that preliminary studies on the physiologic nature of the resistance of monocotyledonous plants to root rot, reported in an accompanying paper (2), indicate that there is some actual toxic substance in the juices of monocotyledonous plants that inhibits the growth of *Phymatotrichum omnivorum*.

Typical dark lesions were found on roots of inoculated and of check corn and sorghum plants in these experiments and also on roots from plants secured from root-rot and root-rot-free areas in fields. Isolations made from such lesions invariably yielded a Fusarium, a species of Rhizoctonia, and other organisms not yet identified, some of which may be the cause of the trouble. The roots of many of the graminaceous crops in Texas, while not attacked by Phymatotrichum root rot, are thus affected by other root diseases that will be the subject of further study.

SUMMARY

A large number of monocotyledonous plants were grown in field plots side by side with susceptible okra, carrot, and cotton plants and copiously inoculated with Phymatotrichum root rot. In the laboratory, carrot roots

and onion bulbs were inoculated in moist chambers. Carrots, onions, hyacinths, cannas, and tuberoses were grown in 5-inch pots and inoculated with sclerotia of *Phymatotrichum omnivorum* taken from pure cultures. In all cases the carrot, okra, and cotton plants succumbed to typical root rot and the causal organism was readily recovered. On the other hand, not a single plant of the 16 different genera of monocotyledonous plants inoculated became infected, succumbed to the disease, or even showed traces of the Phymatotrichum strands on the roots.

Definite, dark reddish brown lesions were found penetrating deeply into the noninoculated as well as the inoculated corn and sorghum roots. Similar lesions were found also on roots of the same plants, as well as on roots of Johnson grass and many other graminaceous plants, growing naturally in root-rot or root-rot free areas. Petri-dish, test-tube, and soil cultures made from these lesions indicate definitely that they were not caused by Phymatotrichum root rot but were induced by other microorganisms.

From the results presented it appears that those monocotyledonous plants tested are neither hosts nor carriers of Phymatotrichum root rot.

COLLEGE STATION,
TEXAS.

LITERATURE CITED

1. EZEKIEL, WALTER N., J. J. TAUBENHAUS, and E. C. CARLYLE. Soil-reaction effects on Phymatotrichum root-rot. Phytopath. **20**: 803–815. 1930.
2. ———, ———, and J. F. FUDGE. Growth of Phymatotrichum omnivorum in plant juices as correlated with resistance of plants to root rot. Phytopath. **22**: 459–474. 1932.
3. KING, C. J., and H. F. LOOMIS. Further studies of cotton root rot in Arizona, with a description of a sclerotium stage of the fungus. Jour. Agr. Res. **39**: 641–676. 1929.
4. PAMMEL, L. H. Root rot of cotton or "cotton blight." Texas Agr. Exp. Sta. Bul. 4. 1888.
5. TAUBENHAUS, J. J., B. F. DANA, W. N. EZEKIEL, W. J. BACH, and J. P. LUSK. A method of inoculation for Phymatotrichum root rot investigations. Phytopath. **19**: 167–170. 1929.
6. ———, ———, and S. E. WOLFF. Plants susceptible or resistant to cotton root rot and their relation to control. Texas Agr. Exp. Sta. Bul. 393. 1929.
7. ———, and WALTER N. EZEKIEL. Studies on the overwintering of Phymatotrichum root rot. Phytopath. **20**: 761–785. 1930.
8. ———, and ———. Resistance of monocotyledonous plants to Phymatotrichum root rot. Texas Agr. Exp. Sta. Ann. Rpt. **43**: 59–60. 1930.
9. ———, and ———. Resistance of monocotyledonous plants to Phymatotrichum root rot. (Abst.) Phytopath. **21**: 119. 1931.
10. ———, and ———. Cotton root rot and its control. Texas Agr. Exp. Sta. Bul. 423. 1931.
11. ———, and D. T. KILLOUGH. Texas root rot of cotton and methods of its control. Texas Agr. Exp. Sta. Bul. 307. 1923.

RESISTANCE OF THE TURK'S-CAP HIBISCUS, MALVAVISCUS CONZATTII, TO PHYMATOTRICHUM ROOT ROT[1]

WALTER J. BACH AND J. J. TAUBENHAUS

Root rot that is caused by the fungus, *Phymatotrichum omnivorum* (Shear) Duggar, is known to attack over 550 species of cultivated and noncultivated plants.[2] In the study of host relationship to Phymatotrichum root rot, it is necessary to determine the susceptibility of cultivated as well as noncultivated plants. It is also imperative to find, if possible, resistant strains or varieties of plants that may be used in areas where the disease is prevalent. The present paper presents data on the relative susceptibility of various plants of the family Malvaceae to Phymatotrichum root rot under field conditions, as well as inoculation experiments with the Turk's-cap hibiscus.

Intensive field studies and observations have been made over a period of years on the degree of resistance or susceptibility of malvaceous plants found growing in Texas to Phymatotrichum root rot.[3] Such plants included cultivated as well as noncultivated species and varieties. In general, plants belonging to the Malvaceae, such as cotton, okra, and roselle, were found to be very susceptible. The only resistant species found in this family was the Turk's-cap hibiscus, *Malvaviscus conzattii* Greenman.

In determining the susceptibility of malvaceous plants growing under field conditions favorable to Phymatotrichum root rot, the susceptibility of the plants studied was ascertained by actual wilting of the plants and by a careful examination of their root systems. Wilting alone is not always a reliable symptom of root rot, since this might be brought about by insect injury, drouth, heat, or other cause. The presence of Phymatotrichum root rot was determined by the wilting of the affected plants and by the presence of the yellowish to buff strands of the fungus mycelium on the infected roots. With woody plants or shrubs, it is sometimes difficult to establish the presence of Phymatotrichum root rot. In such cases, infected plants, even though they do not wilt, shed their leaves rather quickly and not infre-

[1] The writers are indebted to the late Professor H. Ness, Chief of the Division of Botany, Texas Agricultural Experiment Station, and Professor V. L. Cory, Grazing Research Botanist, Substation No. 14, for verification and identification of many of the plant species included in table 1.

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[2] Taubenhaus, J. J., B. F. Dana, and S. E. Wolff. Plants susceptible or resistant to cotton root rot and their relation to control. Texas Agr. Exp. Sta. Bul. 393. 1929.

[3] Bach, W. J., and J. J. Taubenhaus. The resistance of *Malvaviscus conzattii* (*arboreus*) to Phymatotrichum root-rot. (Abst.) Phytopath. 21: 120. 1931.

quently recover by producing new growth. Hence, in dealing with shrubs or woody plants, the roots were given detailed microscopic examination.

Rooted cuttings and more mature plants of the Turk's-cap hibiscus were grown in nursery rows for the inoculation experiments. These plants were inoculated repeatedly. The method of inoculation[4] consisted of inserting roots of freshly wilted cotton or carrot plants in contact with the roots of the plants to be inoculated.

FIELD OBSERVATIONS ON THE RELATIVE SUSCEPTIBILITY OF PLANTS OF THE MALVACEAE FAMILY TO PHYMATOTRICHUM ROOT ROT

Table 1 lists the species of the Malvaceae that have been studied from the standpoint of susceptibility to Phymatotrichum root rot. This list is an alphabetical arrangement of both the cultivated and noncultivated plants. It will be seen from table 1 that, with the exception of the Turk's-cap hibiscus, all the plants of the Malvaceae observed were found susceptible to the disease, some of the plants were highly susceptible, while others were only slightly to moderately so.

RESISTANCE OF TURK'S-CAP HIBISCUS TO PHYMATOTRICHUM ROOT ROT

It has been shown in table 1 that the Turk's-cap hibiscus, under field conditions, is apparently resistant to Phymatotrichum root rot. Although this plant is a perennial woody shrub grown extensively in the Lower Rio Grande Valley as an ornamental or hedge plant (Fig. 1, a) it is rather sensitive to cold and is therefore adapted only to southern Texas and lands of similar climate. The plant is readily propagated by cuttings. Table 2 shows the results of inoculations on Turk's-cap hibiscus. A total of 1,066 attempts were made to inoculate individual Turk's-cap plants, ranging in age from rooted cuttings to full-grown plants. Of this number only 7 of the recently transplanted cuttings showed infection and 6 of these recovered entirely. Two out of 6 1-year-old plants inoculated at College Station showed infection but recovered later. None of the well-established plants succumbed to the disease or showed signs of infection on examination of their root systems. During the 1930 season the Turk's-cap plants were interplanted with cotton, and both the cotton and Turk's-cap were inoculated. The cotton was killed, while the Turk's-cap plants did not succumb (Fig. 1, b). An examination of the root system later failed to show any sign of infection of the latter host.

On December 28, 1929, the entire lot of 142 Turk's-cap plants, which had been inoculated at various times from June 12, 1928, to September 30, 1929,

[4] Taubenhaus, J. J., B. F. Dana, W. N. Ezekiel, W. J. Bach, and J. P. Lusk. A method of inoculation for Phymatotrichum root rot investigations. Phytopath. 19: 167–170. 1929.

TABLE 1.—*Field observations on the relative susceptibility of various cultivated and non-cultivated malvaceous plants to Phymatotrichum root rot*

Name of plant	Relative susceptibility[a]
Abutilon abutilon (L.) Rusby	+
" berlandieri A. Gray	+
" incanum (Link.) Sweet	+
" malacum S. Wats.	+
" megapotamicum St. Hil. Naud.	+
" parvulum A. Gray	+
" pictum Walp.	+
" texense T. G.	+
" triquetrum (L.) Presl.	+
" wrightii A. Gray	+
Althaea ficifolia Cav.	+ +
" rosea Cav.	+ +
Anoda lavaterioides Medic.	+ +
Bastardia viscosa (L.) H.B.K.	+
Callirrhoe digitata Nutt.	+ +
" geranioides Small	+ +
" involucrata (Nutt.) A. Gray	+ +
" linariloba (T. & G.) A. Gray	+
" papaver (Cass.) A. Gray	+ +
" pedata A. Gray	+
" scabriuscula Robinson	+ +
" triangulata (Leavenw.) A. Gray	+
Cienfuegosia sulphurea (St. Hil.) Garcke	+ +
Disella hederacea (Dougl.) Greene	+
Gayoides crispum (L.) Small	+
Gossypium barbadense L.	+ +
" herbaceum Small	+ +
" hirsutum L.	+ +
" peruvianum Cav.	+ +
Hibiscus cardiophyllus A. Gray	+
" coccineus Walt.	+ +
" esculentus L.	+ +
" manihot L.	+
" rosa-sinensis L.	+ +
" sabdariffa L.	+ +
" syriacus L.	+ +
" trionum L.	+ +
Kostelezyka althaeifolia (Chapm.) A. Gray	+
Malachra capitata L.	+
Malva parviflora L.	+ +
" rotundifolia L.	+
" sylvestris L.	+ +
Malvastrum americanum (L.) Torr.	+
" coccinum (Pursh.) A. Gray	+
" leptophyllum A. Gray	+
" spicatum (L.) A. Gray	+
Malvaviscus arboreus Cav.	+ +
" conzattii Greenman	−
" drummondii T. G.	+
Modiola caroliniana (L.) G. Don.	+
Pavonia lasiopetala Schwele.	+ +
Sida angustifolia Lam.	+
" ciliaris L.	+ +
" cuneifolia A. Gray	+ +
" diffusa H.B.K.	+ +
" filiformis Moric.	+ +
" filipes A. Gray	+ +
" hastata St. Hil.	+
" hederacea Torr.	+
" helleri Rose	+
" longipes A. Gray	+
" neomexicana A. Gray	+
" physocalyx A. Gray	+ +
" rhombifolia L.	+
" spinosa L.	+ +
" texana (T. & G.) Small	+
" tragiefolia L.	+ +
" pentachista (A. Gray) Wott. & Stand.	+ +
Sphaeralcea cuspidata (A. Gray) Britton	+
" fendleri A. Gray	+
" hastulata A. Gray	+ +
" incana Torr.	+
" lindheimeri A. Gray	+ +
" lobata Wott.	+ +
" pedata Torr.	+
" pedatifida A. Gray	+
" pumila Wott. & Stand.	+
" subhastata Coult.	+
" tenuipes Wott. & Stand.	+
Wissadula holosericea (Schwele.) Garcke	+
" lozani (Rose) Fries	+ +
" periplocifolia (L.) Griseb.	+

[a] + + Highly susceptible.
+ Moderately to slightly susceptible.
− Resistant.

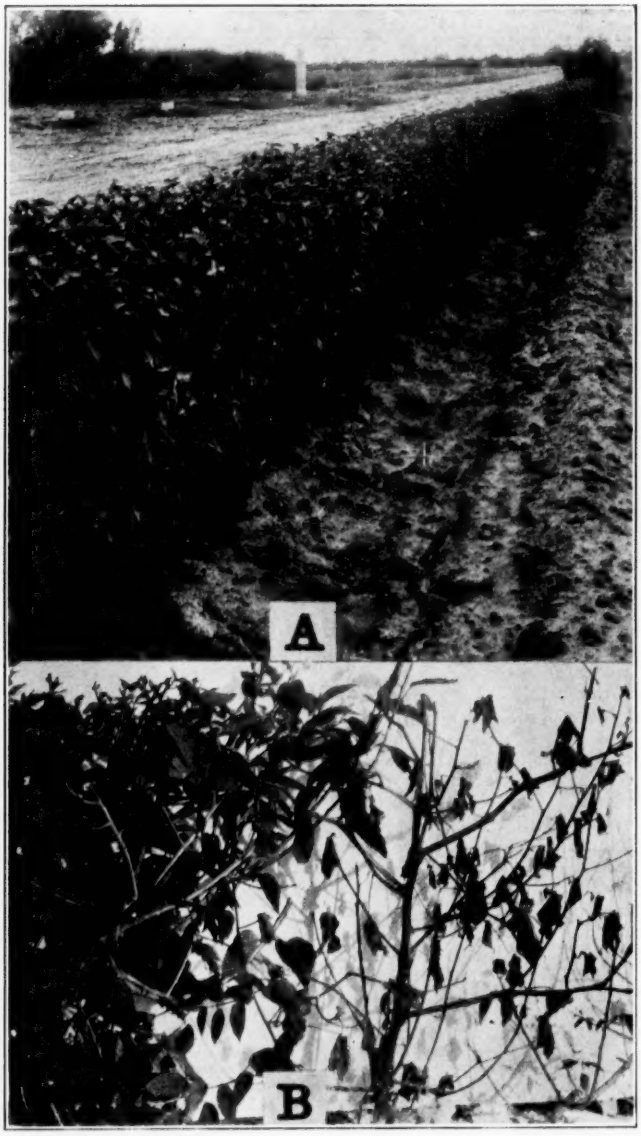

FIG. 1. Resistance of Turk's-cap hibiscus to Phymatotrichum root rot. A. Turk's-cap hedge that has grown vigorously for 3 years without showing any evidences of root rot, although the disease has been prevalent on both sides for several years. B. Uninjured Turk's-cap plant (to left) and dead cotton plant (to right), representative of a row of interplanted plants copiously inoculated with Phymatotrichum root rot.

TABLE 2.—*Resistance of Turk's-cap hibiscus to infection by Phymatotrichum root rot*

Place of inoculation	Host inoculated	Age of plant inoculated	Source of inoculum	Number of plants inoculated	Date of inoculations	Results of inoculations			
						Number of plants infected	Number of days from inoculation to infection	Number of plants recovered	Condition of roots of inoculated plants on examination
Weslaco, Texas	Turk's-cap	1 yr.	Cotton	12	6–12–28	0			Sound
	"	"	Carrots	12	6–12–28	0			"
	"	"	Cotton	20	7–30–28	0			"
	"	"	"	20	8–30–28	0			"
	"	"	"	142	10–12–28	0			"
	"	"	"	29	10–30–28	0			"
	"	1½ yrs.	"	142	6–15–29	0			"
	"	2 yrs.	"	142	7–12–29	0			"
	"	"	"	142	8– 8–29	0			"
	"	"	"	142	8–20–29	0			"
	"	"	"	142[a]	9–30–29	0			"
	"	Rooted cuttings	Carrot	37	3– 8–30 4– 1–30	0			"
	"	"	Cotton	37[b]	7– 7–30 7–24–30	0			"
	"	"	"	29[b]	7– 8–30 7–24–30	3	12–19	1	"
	Cotton		"	77	7–24–30	77	4–96	0	Decayed
	"		"	22	9– 1–30 10–14–30	22	26	0	"
College Station, Texas	Turk's-cap	Rooted cuttings	"	12[b]	9– 1–30 10–14–30	4	26	4	Sound
	"	1 yr.	"	6[b]	9– 1–30 10–14–30	2	26	2	"

[a] All above dug out and roots examined 12–28–29.
[b] Interplanted with cotton and both Turk's-cap and cotton inoculated.

as shown in table 2, were dug out and the root systems examined for evidence of the Phymatotrichum root-rot fungus. The roots of these plants showed no signs of infection. However, it was found that when rooted cuttings of Turk's-cap were planted in the field and immediately inoculated, such plants might become infected. During November, 1930, all of the inoculated Turk's-cap plants at College Station were dug out and examined. Only 4 of the rooted cuttings showed infection. However, by the time these plants were dug out, they had made a new root system and the old infected roots had almost disappeared. Other plants showed very slight signs of infection on the roots; but, apparently, the plant itself was unaffected, for the foliage remained green and luxuriant and no wilting of any kind was noticeable.

From these inoculation experiments, it is concluded that the Turk's-cap hibiscus is highly resistant to Phymatotrichum root rot. It is still unknown whether this apparent resistance is of a physiologic nature or whether it is due to morphologic differences between the roots of this plant and other malvaceous hosts that are highly susceptible to Phymatotrichum root rot. Further research is now in progress and will be reported later.

SUMMARY

In general, plants belonging to the Malvaceae have been found highly susceptible to Phymatotrichum root rot. The Turk's-cap hibiscus appears to be an exception, as it was found to possess a very high degree of resistance. Eighty-two species of plants belonging to the family Malvaceae have been observed and their relative susceptibility to Phymatotrichum root rot indicated. The Turk's-cap hibiscus is the only one of these plants observed to show no infection under field conditions. One thousand and sixty-six attempts at artificial infection of this plant failed to cause infection and death of well-established plants. Further studies are in progress to determine the factors and nature of this resistance.

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GROWTH OF PHYMATOTRICHUM OMNIVORUM IN PLANT JUICES AS CORRELATED WITH RESISTANCE OF PLANTS TO ROOT ROT[1]

WALTER N. EZEKIEL, J. J. TAUBENHAUS, AND J. F. FUDGE

Phymatotrichum omnivorum (Shear) Duggar is an aggressively parasitic fungus, which causes a destructive root rot within a wide range of host plants. Plants susceptible to the disease include such diverse ones as cotton, sweet potato, alfalfa, grape, persimmon, fig, morning-glory, aster, and more than 500 other plants (11). Yet, so far as is known, all of these susceptible plants belong to either the Gymnospermae or Dicotyledoneae. No monocotyledonous plant has yet been found definitely susceptible to Phymatotrichum root rot, as shown in detail elsewhere (12, 13). There would thus appear to be some general difference between dicotyledonous and monocotyledonous plants that enables the root-rot fungus to parasitize perhaps the majority of dicotyledonous plants, as well as many gymnosperms, but makes it difficult or impossible for *P. omnivorum* to attack successfully any of the monocotyledonous plants. Such a difference might be due to morphologic peculiarities preventing infection or growth of the fungus in monocotyledons, or to biochemic peculiarities encouraging growth of the fungus in the case of the susceptible plants or inhibiting it in the case of the resistant plants.

Some preliminary tests of the comparative nutritive value to the fungus of juices expressed from the roots of root-rot-resistant corn plants and of susceptible cotton plants showed much better growth in the juice from the susceptible cotton roots (3, 4). Further experiments have since been carried out with juices from other plants. The work has so far included 4 monocotyledonous plants, all resistant to root rot, and 4 dicotyledonous plants, all susceptible to root rot. Other studies on the same general problem will consider the possible morphologic factors that may be involved in susceptibility or resistance to root rot, and will be reported separately.

HISTORICAL

There appears to be no record in the literature of previous work on the nature of resistance to Phymatotrichum root rot. However, there has been much work on the nature of resistance to other plant diseases (14). Only a few recent studies concerned with the type of work reported in the present paper will be noted here.

[1] Published with the approval of the Director as Contribution No. 176, Technical Series, of the Texas Agricultural Experiment Station.

The most outstanding contributions have been those of Walker and his associates (15, 1) on the basis of resistance to onion smudge. The resistance of red and yellow onions to this disease was proved due to toxic material present in the dry outer scales of these resistant bulbs and apparently consisting, at least in part, of protocatechuic acid. So far as the writers know, this is the only recorded study of physiologic resistance to a disease that has progressed to the discovery of the precise chemical nature of the material apparently involved in resistance.

A number of investigators, however, have found that resistance to the plant diseases with which they worked could apparently be explained by materials extractable from the normal plant tissues, even though these materials have not yet been isolated or identified. Thus, Reynolds (9, 10) found that growth of *Fusarium lini* was depressed in an extract from wilt-resistant flax more than by an extract from a susceptible variety. Working with bark diseases of sour-orange and lemon trees, Klotz (5) found that resistance to the diseases correlated with an inhibitory effect of the bark on certain enzymes produced by the fungi and suggested that similar inhibition of fungus enzymes by plant tissues might explain disease resistance in other plants. Ranker (8) observed inhibition of growth of *Ustilago zeae* in the expressed juices of some but not all of a series of selfed lines of corn resistant to smut, while growth of the fungus was not interfered with by juices from any of the susceptible lines of corn tested. Newton and his associates (6, 7) noted that stem-rust infection of detached leaves of susceptible wheat varieties was in some cases reduced by contact, in the Petri-dish cultures, with extracts from resistant varieties. Ezekiel (2) found that extracts from wheat varieties differed in their ability to support the growth of physiologic forms of *Puccinia graminis tritici* in agreement with the respective resistance or susceptibility of the varieties to the various forms, although a group of the physiologic forms yielded aberrant results so consistently as to suggest that there are at least 2 series of relations involved in resistance to stem rust.

METHODS AND MATERIALS

The general plan of the work reported herewith has been to compare the growth of *Phymatotrichum omnivorum* on juices prepared by the same methods and at the same time from plants susceptible to root rot and from plants resistant to the disease. Large series of cultures prepared from the plant juices were inoculated at the same time and incubated side by side, and colonies harvested from the various series after the intervals specified. The dry weight of the fungus mat was determined, individually for each culture in which there was perceptible growth, by drying the fungus materials in crucibles in the oven.

Except where otherwise specified, the roots used in the preparation of the plant juices were from plants grown at College Station, Texas, and harvested immediately before being used. In all cases, only the underground portions of the roots or storage bodies were used, any surface or greened portions as well as injured portions being discarded. Roots were washed in tap water, rinsed in distilled water, trimmed, and ground in a fine grinder, and the juice then expressed with a hand press. The liquid obtained was strained through absorbent cotton by suction. Portions to be ultrafiltered were removed at this time and passed through a Berkefeld filter, and the ultrafiltered juices were handled thereafter with sterile pipettes and appropriate aseptic precautions. Inasmuch as the juices could be ultrafiltered only with great difficulty, however, most of the series of cultures were run with juices sterilized by heat instead of ultrafiltration. For such series, the undiluted juice was autoclaved for 25 min. at 10-lbs. pressure; refiltered through cotton to remove the coagulum, often precipitated by this first autoclaving; and the juice was then distributed to the individual culture flasks, which were plugged as usual with cotton and autoclaved for 20 min. at 10-lbs. pressure.

Synthetic nutrient solution 70, used in much of this work as a diluent for the juices, is one that has been worked out in the study of the nutritive relations of the fungus (4). It is suitable for the growth of *Phymatotrichum omnivorum* but is not so favorable a substratum as to obscure completely the effect of additions of plant juices. It contains per liter: dextrose, 40 gm.; ammonium nitrate, 1.18 gm.; di-potassium phosphate, 1.35 gm.; magnesium sulphate, 0.75 gm.; potassium chloride, 0.15 gm.; and ferric chloride, 0.25 cc. of 0.5 per cent solution. This medium was used at pH 7.0, any adjustment necessary either for the medium alone or with added plant juices being made with potassium hydroxide solution.

Most of the cultures were in 250 cc. Erlenmeyer flasks, 50 cc. per flask, with 6 to 10 replications of each substratum. It was found in the course of the work on the nutrition of *Phymatotrichum omnivorum* that in some media the fungus would develop more rapidly than in others, as well as to a greater final weight; and also that in some media the weight reached a maximum possibly in 3 weeks, decreasing thereafter, while in other media the maximum might not be reached until 5 weeks or more after the date of inoculation. Accordingly, wherever possible, the cultures were run with 10 flasks of each medium, harvesting sets in triplicate, at the ends of 3 and 4 weeks, and in quadruplicate at the end of 5 weeks.

All cultures during the entire experiment were inoculated with *Phymatotrichum omnivorum* strain 24, the same strain that was used for the nutrition studies (3, 4), and inoculum for each series was taken from the sclerotia produced in a single flask of synthetic media. The masses of

sclerotia were pulled out of the flask by needle and placed in a sterile Petri dish on moist filter-paper. Here, a sterile scalpel was used to cut the mass into small pieces. These pieces varied in weight from about 0.15 mgm. to 0.7 mgm., the average size used for inoculum weighing about 0.4 mgm., oven-dry weight. These weights were negligible as compared to the amount of nutrients ordinarily present in the 50 cc. of solution in the individual cultures, and there was not sufficient material in these sclerotial inocula to support growth of the fungus in distilled water. Individual bits of sclerotia were transferred to the flasks by means of a flat-tip needle, observing the customary aseptic precautions. By this procedure, it was possible to inoculate an entire series of as many as 200 flasks with sclerotia from a single flask. Contaminations were quite rare, and all contaminated cultures were discarded from the series. All the series were incubated in a large culture room, in which during the winter the temperature was held near 26–28° C. by manipulation of heat and ventilation, while in summer it rose to 31–33° C. The results within a given series are thus directly comparable, but this is not true for results in different series.

After the specified periods of incubation, the results were obtained by weighing the mass of fungus growth obtained in each culture. In earlier series each culture was filtered through an asbestos mat in a Gooch crucible, and in later series through alundum crucibles. Care was taken to wash any adhering strands from the flask into the corresponding crucible. The crucibles were dried in the oven at 90–95° C. for 18 hours, to obtain the oven-dry weight. The weights of the triplicate or quadruplicate individual colonies determined in this way were averaged to obtain the average dry weight of colonies as listed in the tables below.

EXPERIMENTAL RESULTS

Cotton and corn-root juices. Preliminary comparison of the growth of the root-rot fungus in juices from cotton roots and from corn roots was started with material prepared on September 26, 1930. Portions of the expressed juices were ultrafiltered through Berkefeld filters, and the remainder used in the preparation of autoclaved media. On account of the small volume of juices available, only dilute media were prepared for this series, each juice being used in dilutions with distilled water and with nutrient solution 70, respectively, to 1/10 and to 1/100 of the original concentration.

Growth in the autoclaved juices was only slightly greater than in the checks (Table 1). However, there was definite, although slight, growth in the dilutions with distilled water, the growth in the diluted cotton juice averaging twice the weight of the growth in the corresponding corn-root juice, while there was no growth in the plain distilled water checks. In

TABLE 1.—*Preliminary comparison of the growth of Phymatotrichum omnivorum in juices expressed Sept. 26, 1930, from the roots of cotton plants (susceptible) and corn plants (resistant) [5 flasks per series, 50 cc. of medium per flask; incubated at 25–32° C., mean = 27.6° C.]*

Composition of media	Average dry weight of *P. omnivorum* colonies after 38 days, in		
	Cotton-root juice	Corn-root juice	Checks
	Mgm.	*Mgm.*	*Mgm.*
Autoclaved juices, diluted with distilled water to 0.1	32.0	15.7	.....
0.01	3.8	2.3	.....
Checks, distilled water alone	.....	.....	0
Autoclaved juices, diluted with nutrient solution 70 to 0.1	449.1	435.0	.....
0.01	442.2	463.5	.....
Checks, nutrient solution 70 alone	.....	.....	382.8
Ultrafiltered juices, diluted with distilled water to 0.1	0	0	.....
0.01	0	0	.....
Checks, distilled water alone	.....	.....	0
Ultrafiltered juices, diluted with nutrient solution 70 to 0.1	0	0	.....
0.01	249.4[a]	0	.....
Checks, nutrient solution 70 alone	.....	.....	438.6

[a] Average of growth in 3 flasks, none in others of this series.

ultrafiltered juices, there was no growth except for a few flasks in 1 series of the cotton juice. This inhibition of growth in the ultrafiltered juices has not yet been checked by repeating this series. However, on October 22, a few culture tubes were prepared with ultrafiltered juices of corn and of cotton roots. These juices were used full strength and hence at 10 times the strongest concentration used in the previous series. The tubes were inoculated with sclerotia of *Phymatotrichum omnivorum*, and within 2 weeks a thick mat of typical Phymatotrichum growth was obtained in every tube of cotton juice. Of the 8 tubes with corn juice, very sparse growth appeared in 1 tube and no growth at all in the remainder.

On November 15, 1930, another series of juices was prepared from cotton and corn roots. These juices were sterilized by autoclaving and

were used to prepare the series of cultures listed in table 2. The fungus colonies were weighed after 30-days' incubation. Growth in the undiluted cotton juice averaged nearly 5 times the weight of growth in the corn juice, and in the juices diluted with distilled water growth was greater in the cotton than in the corn juice, even though the total growth obtained was much less than in the undiluted juice.

Some of the juices prepared for the series above were utilized to set up a further series outlined in table 3. This experiment included a number of series with the juices diluted to 1/6 of the original concentration but with the diluents used in the respective series ranging from the complete nutrient solution 70 down to distilled water. Total growth of the fungus was again greatest in the undiluted juice from the susceptible cotton roots. In each of the 8 diluted series, as well as in the original

TABLE 2.—*Second comparison of growth of Phymatotrichum omnivorum in autoclaved juices expressed Nov. 15, 1930, from roots of cotton and of corn plants, respectively* [*5 flasks per series, 20 cc. of medium per flask; incubated at 25–31° C., mean = 28.2° C.*]

Composition of substrata	Average dry weight of *P. omnivorum* colonies after 30 days, in	
	Cotton-root juice	Corn-root juice
	Mgm.	*Mgm.*
Undiluted, autoclaved juices	455.5	98.8
Autoclaved juices, diluted with distilled water to 0.1	34.2	5.7
Autoclaved juices, diluted with distilled water to 0.01	2.8	2.5

juices, the growth in the cotton juice averaged a definitely greater weight than the growth in the corn juice. It is to be noted that the growth in the undiluted juices in this series corresponded very closely with the growth obtained in the same juices in the previous series (Table 2).

The fact that the juice from the susceptible cotton roots afforded so much better a substratum for the growth of *Phymatotrichum omnivorum* than did the juice from resistant corn roots suggested that the differences in susceptibility of these plants to root rot might be due in part to the presence in the plants of the materials causing these differences in the nutrient value of the juices. The consistent differentiation shown in table 3 indicates that the difference between the juices probably was not a matter of the presence or absence of one or more of the more common nutrient materials. Since, however, the juice expressed from cotton roots was con-

siderably more concentrated than the juice from corn roots (Table 9), it was considered particularly desirable to extend these studies to juices from other plants between which there was less difference in total concentration of the juices.

TABLE 3.—*Growth of Phymatotrichum omnivorum in autoclaved juices expressed from cotton (susceptible) and corn (resistant) roots, diluted in complete and in variously incomplete synthetic solutions [3 flasks per series, 20 cc. of medium per flask; incubated at 26–30.5° C., mean = 28.3° C.]*

Composition of substrata	Average dry weight of *P. omnivorum* colonies after 30 days, in	
	Cotton-root juice	Corn-root juice
	Mgm.	*Mgm.*
Undiluted juices	429.4	78.2
Juices diluted to 1/6 original concentration, with complete nutrient solution[a]	335.6	193.0
with nutrient solution complete except for dextrose	59.1	25.4
with nutrient solution complete except for ammonium nitrate	316.5	173.6
with nutrient solution lacking both dextrose and ammonium nitrate	51.5	14.4
with nutrient solution containing only dextrose	300.3	165.6
with nutrient solution containing only ammonium nitrate	47.5	11.2
with nutrient solution containing only ammonium nitrate and dextrose	296.7	208.2
with distilled water	56.2	12.1

[a] "Complete" nutrient solution (No. 70) contains per liter: dextrose 40 gm., NH_4NO_3 1.18, K_2HPO_4 1.35, $MgSO_4 \cdot 7H_2O$ 0.75, KCl 0.15, $FeCl_3$ trace

Carrot and onion juices. The fleshy roots of carrots are highly susceptible to root rot, both to natural infection in the field and to laboratory inoculations; while the fleshy bulbs of onions appear completely immune from the disease, even when the fungus is introduced artificially through punctures. These storage bodies therefore furnished a convenient source of material for further tests of expressed juices from susceptible and resistant plants. About 12 lbs., each, of carrots and of yellow onions secured from a local grocery store were used to prepare the juices utilized in the cultures listed in tables 4 and 5. The juices obtained, after autoclav-

ing and refiltering, were found very similar in composition. The total percentage of solid matter in the carrot juice was 6.84 per cent as compared with 5.35 per cent in the onion juice; the two liquids, however, contained almost precisely the same amount of total sugars and exactly the same percentage of total proteins, the chief apparent difference being the 0.59 per cent of ash in the carrot juice as compared with 0.25 per cent in the onion juice (Table 9).

Very definite differentiation of growth in these juices was obtained in the series of cultures summarized in table 4. The greatest growth obtained was

TABLE 4.—*Comparison of growth of Phymatotrichum omnivorum in autoclaved juices expressed from carrots (susceptible) and onions (resistant)* [*7 flasks per series, 50 cc. of medium per flask; incubated at 25–31.5° C., mean = 28.2° C.*]

Composition of substrata	Incubation period	Average dry weight of *P. omnivorum* colonies, in		
		Carrot juice	Onion juice	Checks
		Mgm.	*Mgm.*	*Mgm.*
Undiluted juices	3 weeks	694.3	265.2[a]	.....
	5 "	859.4	0	.....
Juices diluted with distilled water to 0.25	3 weeks	255.9	226.8	.....
	5 "	234.6	196.5	.....
to 0.1	3 weeks	156.7	120.5	.....
	5 "	95.1	75.3	.....
Checks, distilled water alone	3 weeks	.....	.....	0
	5 "	.....	.....	0
Juices diluted with nutrient solution 70 to 0.25	3 weeks	596.0	398.4	.....
	5 "	569.3	577.1	.....
to 0.1	3 weeks	550.0	369.0	.....
	5 "	518.2	539.1	.....
Checks, nutrient solution 70 alone	3 weeks	.....	.....	97.1
	5 "	.....	.....	141.4

[a] Results in onion juice erratic, good growth in only 1 flask of the series.

in the undiluted carrot juice. In the undiluted onion juice, good growth was obtained in only 1 flask. Such irregularity in growth in the cultures, while characteristic of the onion juice, was unusual in other media, the growth in the replicate flasks usually coming close to the average. For in-

stance, in the 4 flasks of undiluted carrot juice harvested after 5 weeks, the actual weights of total dry matter ranged from 829.9 mgm. to 884.4 mgm., with the average at 859.4 mgm., as shown.

Differentiation was less pronounced in the diluted juices. Growth in the carrot juice diluted with distilled water was consistently greater than in the corresponding onion series, but the difference was not enough to be of much significance. In the dilutions with nutrient solution 70, growth in the carrot juice was significantly greater than in the diluted onion juice at the end of 3 weeks, but the difference was lowered by the continued, although delayed, growth in the onion juice during the next 2 weeks. In both series, the growth obtained was much greater than in the plain nutrient solution.

The following points appear of particular importance: Growth was encouraged by the carrot juice as compared with the onion juice; growth was inhibited in most cases in the undiluted onion juice but not in the onion juice diluted either with distilled water or nutrient solution; and both the carrot juice and the onion juice added materials that greatly favored growth when added to the synthetic nutrient solution.

Further comparison of carrot and onion juice has been obtained in the course of fractionation studies. Since this work is as yet incomplete, only the check cultures, which are directly comparable to the series just described, will be considered here. These cultures are summarized in table 5,

TABLE 5.—*Growth of Phymatotrichum in autoclaved juices expressed from carrots (susceptible) and onions (resistant)* [*8 flasks per series, 50 cc. of medium per flask; incubated at 22–32° C., mean = 27.4° C.*]

Composition of substrata	Incubation period	Average dry weight of *P. omnivorum* colonies, in		
		Carrot juice	Onion juice	Checks
		Mgm.	*Mgm.*	*Mgm.*
Undiluted juices	3 weeks	519.7	0	.....
	4 "	912.0	0	.....
	5 "	1007.7	0	.....
Juices diluted with nutrient solution 70 to 0.25	3 weeks	477.1	445.3	.....
	4 "	684.7	629.6	.....
	5 "	710.0	735.9	.....
Checks, solution 70 alone	3 weeks	.....	.....	107.5
	4 "	.....	.....	210.4
	5 "	.....	.....	323.1

which includes results from cultures made with the remainder of the juices that were used in the previous work, and in table 6, which gives some results with a second series of juices prepared on June 3, 1931. The results are almost identical with those presented in table 4. Heavy growth was invariably obtained in the undiluted carrot juice. On the other hand, growth occurred in only 1 of the 20 cultures in undiluted onion juice (in this case from white onions) that were included in these series. Juices from white and yellow onions appear equally toxic to *Phymatotrichum omnivorum*. Dilutions of juices with distilled water allowed growth to occur in the onion juice, and this was true also of dilution with the synthetic nutrient solution. Addition to the undiluted juice of the nu-

TABLE 6.—*Growth of Phymatotrichum omnivorum in autoclaved juices expressed from carrots (susceptible) and onions (resistant)* [*10 flasks per series, 50 cc. per flask; incubated at 28.5–35° C., mean = 32.3° C.*]

Composition of substrata	Incubation period	Average dry weight of *P. omnivorum* colonies, in		
		Carrot juice	Onion juice	Checks
		Mgm.	*Mgm.*	*Mgm.*
Undiluted juices	3 weeks	1013.2	0	.....
	4 "	1002.6	159.3[a]	.....
	5 "	802.0	0	.....
Undiluted juices, combined with nutrients of solution 70	3 weeks	1068.2	297.0[b]	.....
	4 "	678.3	309.8[c]	.....
	5 "	1165.7	846.3[d]	.....
Juices diluted with distilled water to 0.25	3 weeks	268.3	338.1	.....
	4 "	235.3	301.4	.....
	5 "	188.1	266.4	.....
Juices diluted in nutrient solution 70 to 0.25[e]	3 weeks	685.9	657.1	.....
	4 "	800.8	954.5	.....
	5 "	613.4	861.2	.....
Checks, nutrient solution 70 alone	3 weeks	.....	.....	174.7
	4 "	.....	.....	303.7
	5 "	.....	.....	360.0

[a] Series variable, colony in one flask only, weighing 478 mgm.
[b] Weights of individual colonies ranged from 148 to 490 mgm.
[c] " " " " " " 41 " 889
[d] " " " " " " 19 " 1301
[e] Nutrient solution 70 undiluted in this series.

trient materials used in solution 70 apparently also counteracted in some way the toxic properties of the undiluted onion juice (Table 6).

Taken together, these results suggested that juice expressed from onions, which are resistant to root rot, contains some substance or substances that at the original concentration of the juice prevent growth of the root-rot fungus, while juice expressed from carrots, which are susceptible to root rot, does not contain this property.

Turnip and canna juices. On February 26, 1931, juice was expressed from stored turnips, and from canna roots freshly dug from the ground. Cultures were prepared from autoclaved series as indicated in table 7.

TABLE 7.—*Growth of Phymatotrichum omnivorum in autoclaved juices expressed from turnips (susceptible) and canna roots (resistant)* [*6 flasks per series, 50 cc. of medium per flask; incubated at 22–32° C., mean = 27.4° C.*]

Composition of substrata	Incubation period	Average dry weight of *P. omnivorum* colonies, in		
		Turnip juice	Canna-root juice	Checks
		Mgm.	*Mgm.*	*Mgm.*
Undiluted juices	3 weeks	0	0	.....
	5 "	0	54.7	.....
Juices diluted with distilled water to 0.25	3 weeks	167.8	87.7	.....
	5 "	102.2	52.0	.....
Juices diluted with solution 70 to 0.25	3 weeks	689.3	333.6	.....
	5 "	544.3	469.1	.....
Checks, solution 70 alone	3 weeks	.....	.....	188.1
	5 "	.....	.....	461.0

This series is the only one that has been tried in which undiluted juice from a susceptible plant (turnip) has inhibited growth of the fungus. Some slight growth occurred in the undiluted juice from the canna roots. On the other hand, fairly definite differentiation was obtained with the diluted juices. With both diluents, the turnip juice accelerated growth, which was higher at the end of 3 weeks than at the end of 5 weeks and was apparently significantly heavier than the growth obtained in dilutions of the canna-root juice.

Sweet potato and nut-grass juices. On April 23, 1931, juices were expressed from commercial stored sweet potatoes and from the fleshy "nuts," or tubers, together with attached stolons and roots, of the sedge commonly called nut grass, *Cyperus rotundus* L. These juices were used to prepare

the series of cultures summarized in table 8. Heavy growth was obtained in the undiluted sweet-potato juice but none in that of the nut grass. As usual, the fungus grew in the dilutions of the material. No significant differences appeared between the growth in the various dilutions of the

TABLE 8.—*Growth of Phymatotrichum in autoclaved juices expressed from sweet potatoes (susceptible) and nut-grass roots, stolons, and tubers (resistant)*
[10 flasks per series, 50 cc. of medium per flask; incubated at 24–29.5° C., mean = 26.3° C.]

Composition of substrata	Incubation period	Average dry weight of *P. omnivorum* colonies, in		
		Sweet-potato juice	Nut-grass juice	Checks
		Mgm.	*Mgm.*	*Mgm.*
Undiluted juices	3 weeks	306.0	0	.....
	4 "	473.3	0	.....
	5 "	947.4	0	.....
Juices diluted with distilled water to 0.25	3 weeks	170.4	297.2	.....
	4 "	321.6	344.3	.....
	5 "	396.8	326.9	.....
to 0.1	3 weeks	106.7	146.6	.....
	4 "	181.9	134.3	.....
	5 "	195.2	112.1	.....
Juices diluted with nutrient solution 70 to 0.25	3 weeks	241.0	332.4	.....
	4 "	479.0	730.5	.....
	5 "	705.8	866.8	.....
to 0.1	3 weeks	153.3	341.9	.....
	4 "	387.3	615.2	.....
	5 "	589.2	680.3	.....
Checks, solution 70 alone	3 weeks	.....	.....	115.4
	4 "	.....	.....	202.0
	5 "	.....	.....	338.7

sweet potato and nut-grass juices, although it appears that with dilutions in distilled water growth was slower but continued to a greater amount in the sweet-potato juice; while in dilutions in the nutrient solution heavier growth was obtained with the nut-grass juice.

Composition of expressed autoclaved plant juices. Partial analyses of the plant juices tested in these cultures are given in table 9. It will be

noted that these analyses throw little light on the differences between the juices that may be involved in the relative value of the juices as substrata for *Phymatotrichum omnivorum*. It is possibly of some importance that each of the 4 juices from plants susceptible to root rot was more concentrated than the juice from the resistant monocotyledonous plant with which

ABLE 9.—*Composition of various plant juices used in these experiments; from analyses of autoclaved, refiltered, and re-autoclaved juices, prepared exactly as for culture substrata*

Sources of juices	Tables in which culture results are given	pH	Composition, as gm. per 100 cc.				
			Total dry matter	Total sugars	Reducing sugars	Proteins (N x 6.25)	Ash
itton roots (susceptible)	Tables	6.0	5.86	.....	.....	.....	0.94
orn roots (resistant)	2 & 3	6.0	2.42	.....	.....	.....	0.49
arrots (susceptible)	Tables	5.7	6.84	4.67	2.43	0.63	0.59
nions (resistant)	4 & 5	5.4	5.35	4.57	3.84	0.63	0.25
urnips (susceptible)	Table	5.8	4.00	2.60	2.46	.....	0.58
anna roots (resistant)	7	6.1	3.11	1.24	0.52	.....	0.90
weet potatoes (susceptible)	Table	5.7	8.49	5.77	1.55	0.18	0.44
ut grass (resistant)	8	5.4	7.91	3.37	0.69	0.55	1.26

it was compared. Yet, the nut-grass juice, in which no Phymatotrichum growth occurred, was more concentrated than any of the juices from the susceptible plants except the sweet-potato juice. There was no consistent difference between the juices with regard to the pH, the total nitrogen content, the total ash content, or the particular constituents of the ash so far as analyzed.

DISCUSSION

These studies of the growth of the root-rot fungus in juices expressed from the underground parts of plants included material from 4 dicotyledonous plants that are susceptible to root rot, as compared with material from 4 monocotyledonous plants that are resistant to the disease. The juice extracted from every susceptible plant except the turnip proved a very good substratum for the fungus, which developed a much greater weight of mycelium than was ever obtained either on the check synthetic solution or in the juice from the resistant plants. Consistently poor growth was secured in the undiluted juices from the 4 monocotyledonous, resistant plants that were included in the study, except for the occasional erratic growth in the undiluted onion extract. Dilution of the juices from sus-

TABLE 10.—*Summary of growth obtained in juices expressed from susceptible plants (upper of each pair) and from resistant plants (lower of each pair) in the undiluted, autoclaved juice and in juice diluted to ¼ its original concentration with distilled water* [*See original tables for details about various series*]

Sources of juices	Reference to table	Average dry weight of *Phymatotrichum omnivorum* colonies, in	
		Undiluted juices	Juices diluted to ¼ with distilled water
		Mgm.	*Mgm.*
Cotton roots (susceptible)	Table 2	455.5	.....
Corn roots (resistant)	"	98.8	.....
Cotton roots (susceptible)	Table 3	429.4	.....
Corn roots (resistant)	"	78.2	.....
Carrots (susceptible)	Table 4	859.4	255.9
Onions (resistant)	"	265.2	226.8
Carrots (susceptible)	Table 5	1007.7	.....
Onions (resistant)	"	0	.....
Carrots (susceptible)	Table 6	1013.2	268.3
Onions (resistant)	"	159.3	338.1
Turnips (susceptible)	Table 7	0	167.8
Canna roots (resistant)	"	54.7	87.7
Sweet potatoes (susceptible)	Table 8	947.4	396.8
Nut grass (resistant)	"	0	344.3

ceptible plants with distilled water resulted invariably in lessening the growth of the fungus, except in the case of the turnip juice. On the other hand, dilution of the juice from resistant plants led usually to a higher average weight, due to the less erratic growth in these diluted liquids. Thus, there was marked differentiation in the relative growth in undiluted juices from the susceptible and resistant plants, but less differentiation in the growth in the diluted juices (Table 10).

The number of plants included in these studies was sufficient to suggest that the differences observed in the nutritive value of the plant juices to the root-rot fungus is perhaps connected with the differences in the resistance and susceptibility of these plants to Phymatotrichum root rot. Susceptibility or resistance to root rot in these cases would then be classified as physiologic and of a nature comparable to that suggested for onion smudge (15), flax wilt (10), and stem rust of wheat (2).

Further study to find, if possible, the nature of the substance or substances involved in this reaction of plant juices to the growth of the root-rot fungus is now under way, and the results will be reported later. For the present, from the fact that the undiluted juice from resistant plants partly or entirely inhibited the growth of the root-rot fungus, while, after dilution with distilled water, this inhibition appeared to be mostly removed, we may draw the tentative conclusion that the difference between the 2 types of plants can scarcely involve lack of essential nutritive material in the resistant plants. The difference would, instead, appear to involve the presence of some specifically inhibitory material in the resistant plants.

SUMMARY

1. *Phymatotrichum omnivorum*, the fungus that causes root rot, has been grown in series of cultures prepared with juices expressed from 4 monocotyledonous plants (corn, onions, cannas, and nut grass) resistant to the disease and from 4 dicotyledonous plants (cotton, carrots, turnips, and sweet potatoes) susceptible to the disease. The oven-dry weight of the mycelium was determined.

2. Growth of the fungus was markedly inhibited in the undiluted, though autoclaved, juices from all of the resistant plants, while profuse and heavy growth was obtained with juices from 3 of the 4 susceptible plants.

3. With diluted juices, good growth was obtained even in series from the resistant plants.

4. It is therefore concluded that monocotyledonous plants resistant to root rot apparently contain materials that in sufficiently high concentration can inhibit the growth of the root-rot fungus, and that the resistance of these plants to the disease is probably based, at least in part, on the presence of this material or materials. Further study is under way to determine more accurately the materials involved.

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LITERATURE CITED

1. ANGELL, H. R., J. C. WALKER, and KARL PAUL LINK. The relation of protocatechuic acid to disease resistance in the onion. Phytopath. **20**: 431–438. 1930.
2. EZEKIEL, WALTER N. Studies on the nature of physiologic resistance to Puccinia graminis tritici. Minn. Agr. Exp. Sta. Tech. Bul. 67. 1930.
3. ————, D. C. NEAL, PAUL R. DAWSON, and E. B. REYNOLDS. Report of the fourth annual cotton-root-rot conference. Phytopath. **21**: 957–964. 1931.
4. ————, J. J. TAUBENHAUS, and J. F. FUDGE. Nutritional studies on Phymatotrichum omnivorum. (Abst.) Phytopath. **21**: 120. 1931.
5. KLOTZ, L. J. Inhibition of enzymatic action as a possible factor in the resistance of plants to disease. Science, n. s. **66**: 631–632. 1927.

6. NEWTON, R., and J. A. ANDERSON. Studies on the nature of rust resistance in wheat. IV. Phenolic compounds of the wheat plant. Canad. Jour. Res. 1: 86–99. 1929.
7. ————, J. V. LEHMANN, and A. E. CLARKE. Studies on the nature of rust resistance in wheat. I. General introduction. II. Physico-chemical properties of host-cell contents. III. Culture and injection experiments to demonstrate inhibiting or accessory substances. Canad. Jour. Res. 1: 5–35. 1929.
8. RANKER, EMERY R. The nature of smut resistance in certain selfed lines of corn as indicated by filtration studies. Jour. Agr. Res. 41: 613–619. 1930.
9. REYNOLDS, ERNEST SHAW. Nutritional studies on Fusarium lini. Plant Physiol. 1: 151–164. 1926.
10. ————. Studies on the physiology of plant disease. Ann. Mo. Bot. Gard. 18: 57–95. 1931.
11. TAUBENHAUS, J. J., B. F. DANA, and S. E. WOLFF. Plants susceptible or resistant to cotton root rot and their relation to control. Texas Agr. Exp. Sta. Bul. 393. 1929.
12. ————, and WALTER N. EZEKIEL. Cotton root-rot and its control. Texas Agr. Exp. Sta. Bul. 423. 1931.
13. ————, and ————. Resistance of monocotyledons to Phymatotrichum root rot. Phytopath. 22: 443–452. 1932.
14. WALKER, J. C. On the nature of disease resistance in plants. Trans. Wis. Acad. Sci., Arts, and Letters 21: 225–247. 1924.
15. ————. Disease resistance to onion smudge. Jour. Agr. Res. 24: 1019–1040. 1923.

REPORT OF THE TWENTY-THIRD ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

THE NEW ORLEANS MEETING

The American Phytopathological Society held its twenty-third annual meeting from Tuesday through Thursday, December 29–31, 1931, in conjunction with its southern division, with about 125 pathologists in attendance. Excellent space for meetings was provided by the St. Charles Hotel (headquarters) and Tulane University.

Abstracts of the 89 papers delivered before the Society's several sessions were published in the January, 1932, number of PHYTOPATHOLOGY. These papers may be grouped as follows: General (including two invitation papers), 3; potato diseases, 5; fruit diseases, 12; biologic specialization, 8; tobacco and sugar-cane diseases, 8; vegetable diseases, 16; mycology, 8; trees and ornamentals, 9; cereal diseases, 8; corn diseases, 8; miscellaneous crop diseases, 4.

Three joint sessions were held as follows: with Section G of the A. A. A. S., Potato Association of America, and the Mycology Section of the Botanical Society of America.

Extension work in plant pathology, with special reference to southern extension problems in the light of present conditions, was the subject outlined for discussion at the meeting of the extension pathologists on the afternoon of December 29. The importance of reviewing and revising programs of work to see that they meet the needs and are economically sound and in line with the State programs was stressed, as was also cooperation with other specialists in conducting the work. The conference was informed of a method of conducting demonstrations on a large scale in Iowa. Contests for large yields of various crops, as illustrated by "400-Bushel Potato Clubs," were considered. Among other subjects discussed were: Zinc-lime sprays for peaches; dipping sweet-potato sprouts; need of a standard method of making Bordeaux mixture; control of cucumber and watermelon diseases; and need of revision of standards for certifying Irish potatoes.

In a round-table session on quarantine and regulatory work discussion of "Nematodes as a Quarantine Problem" brought out vividly the meagerness of our knowledge of the pest status of these organisms, and the views expressed on "Uniformity in Nursery Inspection" stressed the general need of such uniformity to be best secured by interstate agreement arrived at through the plant-board system.

The phytopathologists' dinner, with 143 attending, was a great success. Under the leadership of Dr. C. H. Edgerton a committee of plant pathologists from the Southern States provided musical entertainment by students of Southern University, and other much appreciated specialties.

OFFICERS AND REPRESENTATIVES

The following officers and representatives were chosen:

President, F. D. Heald, State College of Washington, Pullman, Wash.

Vice President, J. G. Dickson, University of Wisconsin, Madison, Wis.

Secretary-Treasurer (three years), F. C. Meier, U. S. Department of Agriculture, Washington, D. C.

Councilor (two years), L. O. Kunkel, Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.

Editors (three years), H. B. Humphrey, Editor in Chief, U. S. Department of Agriculture, Washington, D. C.; H. M. Quanjer, Editor for Europe, Instituut voor Phytopathologie, Wageningen, Holland; Annie Rathbun Gravatt, U. S. Department of Agricul-

ture, Washington, D. C.; and Eubanks Carsner, Citrus Experiment Station, Riverside, Calif.

Associate Editors (three years), J. C. Gilman, Iowa State College, Ames, Iowa; W. D. Valleau, University of Kentucky, Lexington, Ky.; W. F. Hanna, Manitoba Agricultural College, Winnipeg, Canada; and Jessie I. Wood, U. S. Department of Agriculture, Washington, D. C.

Business Manager (one year), F. C. Meier, U. S. Department of Agriculture, Washington, D. C.

Advertising Manager (one year), R. S. Kirby, Pennsylvania State College, State College, Pa.

Representatives on the Council of the American Association for the Advancement of Science (one year), D. Reddick, Cornell University, Ithaca, N. Y.; and C. W. Edgerton, Louisiana Agricultural Experiment station, Baton Rouge, La.

Member of the Board of Governors of the Crop Protection Institute (three years), W. H. Martin, New Jersey State Agricultural Experiment Station, New Brunswick, N. J.

The following temporary committees were appointed to serve throughout the meetings:

Auditing Committee, H. A. Edson and J. F. Adams.

Committee on Elections, H. T. Cook, Duke Layton, and H. N. Hansen.

Committee on Resolutions, H. W. Anderson, E. C. Stakman, and G. F. Weber.

REPORT OF THE SECRETARY-TREASURER, 1931

The final check up of membership last year showed a total of 753. Eighty-seven new members elected at the Cleveland Meeting and 3 former members reinstated during the year brought this number to 843. During 1931, 4 members were lost through death, 8 resigned, and 43 were dropped from the Society for nonpayment of dues. The total membership, therefore, now stands at 788. Of this number we have 85 paid-up life members, 89 life-sustaining, and 614 regular members. There are 48 new applicants for membership. Election of these will give us a total of 836.

STATEMENT OF ACCOUNTS FOR 1931, AS OF DECEMBER 15, 1931

Receipts:			
Balance from 1930			$3,182.07
Annual dues: 1930	$ 20.00		
1931	1,709.55	($260.25 life)	
1932	2,215.37	($543.82 life)	
1933	.50		3,945.42
Interest on checking account			43.55
Donations to Lyman Memorial Fund included in checks for dues			22.00
Donations to Butler Fund			139.32
Sales received with dues			19.20
Subscription received with dues			6.52
Refund on advance of funds to Secretary-Treasurer for Cleveland meeting			3.96
Balance from Phytopathologists' dinner in Cleveland			43.00
Total Receipts			$7,405.04
Expenditures:			
Member subscriptions transferred to PHYTOPATHOLOGY (1931, part 1930)			$3,688.24

Secretarial work	455.53
Printing (programs for 1930 and 1931, preliminary programs, abstracts, special notices, application blanks, etc.)	215.55
Advance of funds to Secretary-Treasurer for expenses of Cleveland meeting	75.00
Butler settee	91.68
Postage and stamped envelopes	83.49
Donations transferred to Lyman Memorial Fund	22.00
Multigraphing 1930 press releases	15.00
Telephone and telegraph	7.21
Checks returned by bank	30.00
Furniture and supplies	47.30
Sales transferred to PHYTOPATHOLOGY	15.00
Subscription transferred to PHYTOPATHOLOGY	6.52
Domestic mailing list	1.31
Balance on hand	2,651.21
	$7,405.04

SINKING FUND

The Sinking Fund, obtained by deducting $5.00 (formerly $6.00) from each life-sustaining-membership payment, is now $7,236.17, of which $6,500.00 is invested in first-mortgage notes. The remaining $736.17 is now in the Society's checking account and will be invested as recommended by the investment committee.

Respectfully submitted,

F. C. MEIER, *Secretary-Treasurer.*

REPORT OF THE BUSINESS MANAGER OF PHYTOPATHOLOGY FOR 1931

STATEMENT OF ACCOUNTS FOR 1931, AS OF DECEMBER 15, 1931

Receipts:

Balance from 1930	$1,083.26
Subscriptions, 1931	2,579.16
Subscriptions, 1932	748.06
Subscriptions, other years	36.31
Sales of back volumes and numbers	233.36
Advertising, 1930	76.52
Advertising, 1931	795.04
Interest on Sinking Fund	390.00
Member subscriptions for 1930 (balance)	786.00
Member subscriptions for 1931 (part)	2,857.32
Member subscriptions (balance earlier years)	44.92
Excess payment on group of subscriptions	26.00
Dues to The American Phytopathological Society received with subscriptions	5.00
Tropical Plant Research Foundation for color plate for Priode article	377.50
For special notice in July article	3.00
Refund on insurance of old volumes	12.80
	$10,054.25

Expenditures:

Manufacturing PHYTOPATHOLOGY:			
Vol. XX, No. 12	$497.11		
Vol. XX, Index	127.93		
		$ 625.04	
Vol. XXI, No. 1	735.00		
No. 2	581.17		
No. 3	554.67		
No. 4	559.18		
No. 5	782.58		
No. 6	355.94		
No. 7	687.99		
No. 8	420.24		
No. 9	429.91		
No. 10	419.24		
No. 11	495.45		
Vol. XXI, Cuts	806.48		
Color plate	377.50		
Postage	429.43	7,634.78	8,259.82
Secretarial work for Business Manager			60.00
Expenses of Editor in Chief			67.53
Postage and envelopes			25.00
Expenses of Advertising Manager			128.57
Refund of excess payment			26.00
Transferred to The American Phytopathological Society for dues			5.00
Refund to Bayer Semesan Co. for patron membership dues			100.00
Refund on sales			1.00
Reprints and mailing lists			62.91
Insurance on early volumes			68.16
Inventory of early volume			3.33
Expenses of Business Manager and Advertising Manager on trip to Lancaster, Pa.			16.60
Supplies			3.00
Balance on hand			1,227.33
			$10,054.25

There were 565 subscribers (nonmembers) to PHYTOPATHOLOGY in 1931. With 6 complimentary subscriptions and 788 members of The American Phytopathological Society, this brings the total circulation of the Journal to 1,359.

To Dr. J. F. Adams, who is retiring after a period of 8 years' successful service as advertising manager, the Society owes much. From the beginning his energetic efforts to build up advertising as a source of income brought results that have enabled the Society to print a better journal.

Recognition should also be made of the service rendered by Dr. C. E. Temple, of Maryland, who for a number of years has voluntarily handled the distribution of back numbers of the Journal as printed by Williams & Wilkins; also to the University of Maryland, which has provided storage for this stock.

To our editor in chief, Dr. H. B. Humphrey, who often against his personal inclination has resolutely limited the number of printed pages during the year, we owe the fact that the sound program for increased income initiated during the term of Dr. R. J.

Haskell, my predecessor, has made it possible for the Journal to attain a much improved financial footing.

Respectfully submitted,

F. C. MEIER, *Business Manager.*

REPORT OF THE EDITOR IN CHIEF

The consistent improvement and maintenance of the standards of excellence of our Journal have been live subjects of interest and thought in the mind of each member of the editorial staff. Many have been the expressions, both written and spoken, testifying to the fact that PHYTOPATHOLOGY has from month to month reflected not only the solicitude of its editors but also the awakened intelligent interest of its contributors and readers. It would seem that more than ever is there evidence of the fact that the improvement and increased usefulness of our Journal are a responsibility resting not alone upon the editors but, in a very real sense, upon The American Phytopathological Society as a whole.

We realize that there yet remains no little need of further improvement. It may be that purely voluntary, nonrenumerated editorial service will never bring about the editorial finish that characterizes certain other scientific periodicals. Nevertheless, "the game is worth the candle." With the continued effort on the part of each contributor to organize his subject-matter and to polish off the finished product in the form of readable, lucid, and scientifically excellent manuscripts we can and inevitably must raise the standard of PHYTOPATHOLOGY.

It still seems necessary to admonish some of our contributors to devote more attention to the art of science writing. Prolixity is inexcusable. To express in 30 words a fact or thought requiring but 10 is an indefensible waste of time and money. Publication of the current volume of our Journal has cost the Society $7,888.88, or $6.53 per page. It is very probable that we paid too dearly for the actual subject-matter presented in the more than 1,200 pages. When we prepare a manuscript let us assure ourselves that those supporting PHYTOPATHOLOGY will not have to pay for any "sand-in-the-sugar" contributions.

The 21st volume of PHYTOPATHOLOGY comprises 1,207 pages of printed matter and illustrations, classified as follows: 89 articles, 18 phytopathological notes, 3 reports, 6 book reviews, 98 abstracts (2 by title only), 1 color plate, and 256 text figures. During the period January 1 to December 31, 1931, approximately 121 manuscripts of articles, phytopathological notes, reports, book reviews, etc., and 89 manuscripts of abstracts (1 by title only) were submitted. Of this number, 19 manuscripts were returned to the authors for revision and 2 were rejected. Of the several manuscripts received during the current year, 11 articles, 1 phytopathological note, 1 book review, and 89 abstracts (1 by title only) are now in press. Approximately 28 per cent of the papers, exclusive of abstracts, appearing in volume 21 were contributed in part or wholly by employees of the U. S. Department of Agriculture.

Summarized report for the triennium, 1929 to 1931. The 19th, 20th, and 21st volumes of PHYTOPATHOLOGY comprise 3,365 pages of printed matter and illustrations, classified as follows: 264 articles, 63 phytopathological notes, 8 reports, 12 book reviews, etc., 357 abstracts (17 by title only), 40 plates, and 640 text figures. During the period January 1, 1929, to December 31, 1931, approximately 385 manuscripts of articles, phytopathological notes, reports, book reviews, etc., and 355 manuscripts of abstracts (18 by title only), exclusive of those rejected, were submitted and presented at the annual meetings of The American Phytopathological Society and the meetings of the Pacific and Canadian divisions of the Society. Of this number, 73 were returned to the authors for

revision, 18 were rejected, and 6 were voluntarily withdrawn. Of the total number of manuscripts received, 48 are now on the printer's waiting list. Approximately ⅓ of the articles published in volumes 19, 20, and 21 were contributed by employees of the U. S. Department of Agriculture. From sources exclusive of continental United States, there have been received and accepted 73 contributions, 23 of which were submitted from Canada; 14, Hawaii; 5 from each of the following: Great Britain, India, and The Netherlands; 4, Peru; 3, each, Cuba and Porto Rico; 2, each, Palestine and China; and 1, each, from the Philippines, Santo Domingo, Argentina, Colombia, France, Union of South Africa, and Tanganyika, Africa. From these figures and figure 1 it is readily

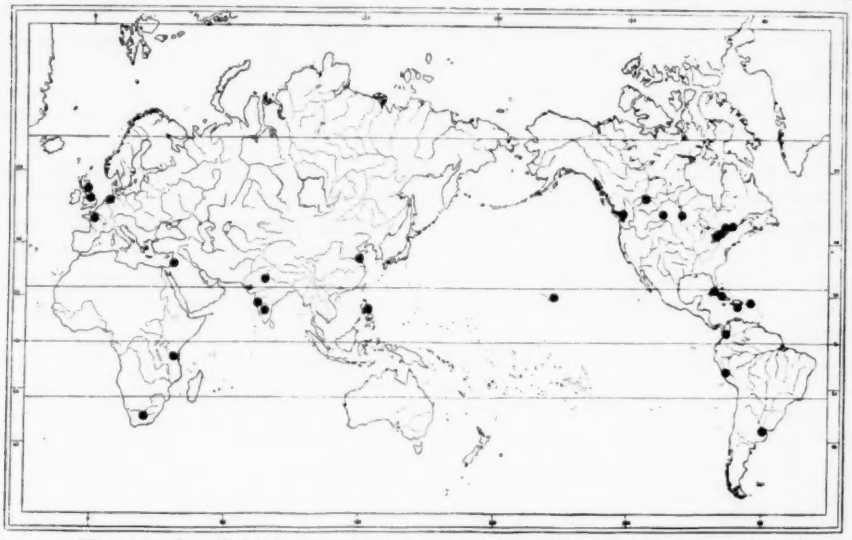

FIG. 1. Mercators'-projection map showing geographical distribution of points of origin, outside of continental United States, of contributions to PHYTOPATHOLOGY during the triennium 1929–1931

patent that our Journal is, in fact as well as name, international. Publication of an occasional contribution in certain languages other than English would extend its usefulness and enlarge its internationality.

The editor wishes here to make grateful acknowledgment of the unstinted cooperation and exceptional service of the several members of the editorial board. Special thanks are due Mr. J. Marion Shull for his valued help and advice in the arrangement and lettering of illustrations accompanying the several contributions and to Frances W. Todd for invaluable editorial and clerical assistance.

Respectfully submitted,

H. B. HUMPHREY, *Editor in Chief.*

REPORT OF THE ADVERTISING MANAGER

For the first time in the past 7 years, the total of advertising secured during 1931 is below the average. The previous 5-year average has been 73 pages. The 1931 total dropped to 54¾ pages. For the 12 issues of PHYTOPATHOLOGY published during 1931, there appeared a total of 83 advertisements distributed as follows: 47 one-page, 15 one-half page, and 21 one-fourth page advertisements.

The renewal of contracts for the coming year is always started during the preceding fall, usually in September. Greater solicitation and a broader field had been covered for business during 1932. Replies received indicate further retrenchment in budgets for advertising. In several instances a 50 per cent cut in the budget for 1932 has been made and many replies indicate that curtailment has been so drastic that they regret the possibility that no advertising can be placed for 1932. At this time, the total of advertising secured for 1932 is 60 per cent of the total secured during 1931.

Respectfully submitted,

J. F. ADAMS, *Advertising Manager.*

COMMITTEE ON INVESTIGATION OF FOREIGN PESTS AND PLANT DISEASES

Your committee begs to call attention to certain plant diseases that have come to our attention during the past year and that are not yet known to occur in this country, but present sufficient danger to our crops to be investigated before they have became introduced.

A particularly outstanding case is the potato rust, *Puccinia pittieriana* until recently known only from Costa Rica and Ecuador where it was very destructive to potatoes and tomatoes. In 1929 it was found in Peru and in 1930 in *Solanum demissum* in Mexico by Dr. Donald Reddick.

The range of Lima-bean scab (*Elsinoë canabaliae*) is now included to cover Mexico, Gautemala, and Costa Rica, in addition to Cuba and Porto Rico where it was previously known. This disease is unquestionably of great importance in Cuba, and information is urgently needed as to its pest status in the United States.

We wish to emphasize the importance of avoiding new importations of pathogenic races of plant parasites. A new race of corn smut is of as much importance pathologically as a new species of smut.

In this connection there seems to be some doubt as to the distinctiveness of the various species of Sphaceloma, at present recognized as causing citrus scab in this country and the West Indies. The exact relationship of these species or races should be established in order that the further importation of citrus may be properly regulated.

C. R. ORTON, *Chairman,*
W. A. MCCUBBIN,
F. D. FROMME.

COMMITTEE ON QUARANTINE AND REGULATORY WORK

The attendance at the session on Quarantine and Regulatory Work held during the New Orleans meeting was made up as follows: Washington, D. C., 3; Mississippi, 4; Minnesota, 2; and one each from Delaware, Maryland, New Jersey, North Carolina, and Texas—total, 14.

The discussion on "Nematodes as a Quarantine Problem" was ably introduced by R. F. Poole, of North Carolina, who brought up six phases of the subject for consideration, accompanying his presentation with comments designed to bring out the difficulties confronting us in each case. The points presented were as follows:

(1) Are nemas already so widely distributed that further precautions in dissemination and spread may be of doubtful value?
(2) Are nemic diseases increasing in importance or have they always been severe but not properly diagnosed?
(3) Are nemas restricted to southern climatic and soil conditions and controlled by these conditions in northern States.

(4) Are nematode species sufficiently restricted to crop species that rotation practices can be regulated sufficiently to obtain control or satisfactory reduction in losses?

(5) Are methods of seed and plant treatment so effective in control that plant quarantine measures are unnecessary?

(6) Are nemic diseases and methods of diagnosing the nematode species sufficiently accurate and well known to warrant quarantine procedures?

The discussion that followed brought out the attitudes of the various State representatives as to how nemas are regarded as a regulatory problem in each State. The general opinion seemed to be that quarantine or regulatory action would be advisable only in special cases, particularly where enough was known about the nema involved to justify this type of action.

From a number of quarters the complaint was made that too little is known about specific identities, life histories, host range, damage, and control to provide a sound basis for judgment whether regulatory measures would be useful or unprofitable.

Questioning of the State representatives present elicited the fact that in none of these States was any general investigation of the nematode problem in progress, although in some cases attention was being given to specific diseases due to nemas.

Mention was made of the considerable damage on sweet potatoes caused by the bulb nema, and the meeting adopted the following resolution for tranmission by the secretary of the Society to the proper Federal authorities:

> "That in view of the fact that the bulb nematode (*Tylenchus dipsaci*) has been reported recently as serious on the sweet potato in New Jersey, and since the possiblity exists that this may become a very serious disease of this important crop, it is the opinion of this group that immediate steps be taken to determine the present distribution of the disease. This should no doubt be done through surveys of storage houses this winter and spring, as well as through careful inspection of plant beds where poor germination is reported, since this poor germination is one of the symptoms of the presence of this nema. It is urged also that all available information on this disease of the sweet potato be assembled and placed in the hands of plant pathologists, horticulturists, county agents, plant boards, and all other interested parties."

The second subject for discussion was well introduced by Dr. Clay Lyle, of Mississippi, who pointed out the various difficulties arising from the endless variation in nursery-inspection certificates, requirements, standards, and methods of inspection now in effect in different States; the efforts now being made by regional and national plant boards to bring about more uniformity in these matters; and the responsibility of the plant pathologist in helping to solve the problems involved.

In spite of this very promising beginning the discussion had to be curtailed by shortness of time, so that little of constructive value came out of the session on this subject.

W. A. MCCUBBIN, *Chairman.*

COMMITTEE ON INTERNATIONAL RELATIONS

Your committee was informed that at a meeting of the General Assembly of the International Union of Biological Sciences held in Brussels in July, 1931, the question of the status of phytopathology in the Union was settled by erecting a subsection for pathology in the botanical section. Dr. Johanna Westerdijk was named chairman of the

subsection. The former president of the Union has stated in a letter (the *Proceedings* are not yet available) that further organization of the subsection will probably await adherence of the principal national societies.

Your committee has examined the statutes of the International Union of Biological Sciences and is of the opinion that the aims and purposes of the Union are substantially in accord with the "principles" adopted by this Society at its Des Moines meetng. Under the very broad and thoroughly international statutes of the International Research Council the Union enjoys a very great freedom of operation amounting practically to autonomy.

The Union is a going concern and the subsection for phytopathology can be made just as active and as useful in the furtherance of international relations as the constitutent national organizations choose to make it.

The following resolutions are, therefore, recommended to the Society for adoption:

1. That in view of the prevailing sentiment in the Society for closer international relations as expressed at various times, but in particular at the Des Moines Meeting, The American Phytopathological Society look with favor upon adherence to the International Union of Biological Sciences as at present constituted under the International Research Council.

2. That the Council be empowered to institute negotiations looking to adherence to the Union.

3. That a copy of this resolution be transmitted to each of the biological organizations now in session in New Orleans.

4. That, if the Society adopt the foregoing resolutions, this Committee be discharged.

R. J. HASKELL, *Chairman.*

PRESS SERVICE

During the past year the Press Service has continued to release for the public press stories based on the papers presented at the annual meetings and to assist the Society in any matters pertaining to its publicity.

Better to serve the Society and to obtain the journalist's view of the material handled, Don B. Reed, day city editor of the Washington *Post*, was taken into consultation. Following Mr. Reed's excellent suggestions, a few of the papers for the New Orleans meetings were given amplification and released as special features, while the remainder were grouped according to crops or groups of crops, covered, and sent out as material for special columns or to be used as "punk", at the discretion of the receiving editor.

Press releases of this nature are very useful in presenting to the public the achievements of plant pathologists, yet it is a rather thankless task since there seldom is any way in which the use of material may be checked. However, from the reports that have filtered in already this year and those of past years, it is most gratifying to the Press Service to report not only a wider dissemination of the material but an apparent increase in the number of papers using it.

Besides the usual press releases for the annual meetings, the Press Service has cooperated with the Secretary-Treasurer of the Society in preparing the report of the meetings published in *Science* and in writing advertisements for the Society and for PHYTOPATHOLOGY.

W. A. WHITNEY, *Press Representative.*

COMMITTEE ON NECROLOGY

During the year 1930, there was one death not included in the previous report, namely, that of Mr. Sanpatiro Umetu. Mr. Umetu died in Japan in 1930, but it has been impossible to determine the exact date of his death.

During the calendar year 1931, there have been four deaths, as follows:

Mr. Frederick John Pritchard, died January 13, 1931.
Dr. Louis Herman Pammel, died March 23, 1931.
Dr. Warner Jackson Morse, died March 25, 1931.
Dr. Calvin Henry Kauffman, died June 14, 1931.

A. G. JOHNSON, *Chairman*,
G. P. CLINTON,
M. B. WAITE.

REPORTS OF OTHER COMMITTEES AND REPRESENTATIVES

Report of Activities of the Division of Biology and Agriculture of the National Research Council. The elector from the Society of American Bacteriologists and I selected Dr. James M. Sherman to represent the two societies.

A. J. RIKER,
Elector Representing The American Phytopathological Society.

The American Association for the Advancement of Science. A brief informal report of the representatives on the Council of the American Association for the Advancement of Science was presented by C. W. Edgerton.

Report on the American Type Culture Collection, 1931. The following is a report on the portion of the American Type Culture Collection maintained by the Division of Mycology and Disease Survey, of the Bureau of Plant Industry, for the year 1931:

Number of cultures sent to headquarters in Chicago during the year	213
Number of cultures in stock Dec. 18, 1930	654
Number of cultures in stock Dec. 8, 1931	784

In addition to the cultures sent to Chicago, approximately 150 cultures have been supplied to departmental investigators and cooperators.

I regret to report that the funds heretofore provided to maintain the collection and carry on the work are almost exhausted, and no more can be obtained from the same or any other source at present known. It was hoped by some of the supporters of the project that it could be made self-supporting, but this does not seem to be possible. Some new method of financing or carrying on the work must be found, if the collection as a whole is to be maintained. If any member of our Society can suggest within the next few months ways or means of continuing the work, such suggestion would be gratefully received.

C. L. SHEAR.

Committee on Chicago Century of Progress Exposition. Dr. L. R. Jones was appointed chairman of this committee but, owing to his absence in the Orient, he deputized H. W. Anderson to act as chairman during his absence. Before leaving, Dr. Jones sent the present chairman some general suggestions in regard to possible methods of interlocking our exhibit with other phases of science, especially the basic science of botany and the applied science of agriculture. I quote his letter to the other members of the committee:

"Dr. Woods, as an active member of the Science Advisory Committee, is well informed as to progress to date and is especially pleased at the action of our Society in proffering its services through this Committee. He promises to cooperate by keeping us advised of further developments, will welcome suggestions or general aid, and will look to us for more specific services as plans take definite form. There is now before Congress a bill providing financial aid. He will advise us when this passes as to provision and possibilities under it. Meanwhile he recently sought advice from his departmental and other Committee associates and as a result has prepared certain 'Suggestions for the Agricultural Exhibit.' I am asking him to send a stencil copy of this to each of you for your information. Meanwhile I am inclosing a more general printed pamphlet, which he gave me, for your information.

"Dr. Woods expects the Congressional Bill to be acted upon at this session but does not know what limitations may be placed on its use. It is my present conception that the scientific exhibits may take two general forms: (1) A coordinated central group dealing with the Century of Progress in the basic sciences; (2) other related exhibits dealing with the human relations or applications of science. We may assume that mycology, bacteriology, and physiology may receive consideration in the first group, and I believe that the basic concepts of parasitism (the 'germ theory of disease') as related to animal and plant pathology may also deserve consideration. It is in the second group that the applications to plant cultural practices—and probably that which deals with specific diseases as such—may find place.

"While waiting for more specific advice on these points from Dr. Woods, I make the following suggestions and request:

"(1) That Dr. Anderson learn whatever he may, especially through relations with Dr. W. P. Flint (as a member of the Science Advisory Committee), concerning the plans of the entomologists for corresponding exhibits, including what place these may have in the central or basic exhibits. Also whatever may be learned as to financial support expected for such exhibits, including possible State funds.

"(2) That Dr. Link learn whatever he may upon these and related matters, especially through relations with the officials of the central administration in Chicago."

The acting chairman has taken occasion to confer with Dr. Gregory and Dr. Link during the past summer in order to get their viewpoints as to the best method of planning the exhibits.

There seem to be several possible methods of exhibiting the science of plant pathology.

1. The committee might act in an advisory capacity for those in charge of the general agricultural and botanical exhibits.

2. Special funds and space might be secured to be devoted to plant pathology alone.

It seems to be the idea of the central committee of 50 of the Century of Progress that all exhibits should be arranged in such a way as to make a continuous story; in other words, that the specialized sciences be grouped around the basic science to which they are most closely related.

In the case of plant pathology, the difficulty arises from the fact that it may be regarded as a phase of biology or as an applied science in agriculture. It seemed, therefore, that the first question to decide was whether we should ally ourselves with the agricultural group or with the botanical group or both.

Some general plans were suggested by both Dr. Gregory and Dr. Link, but before any very definite plans could be carried out we thought it best to learn something about the financial help we could depend upon to carry out these plans.

Dr. Jones suggested in his letter that the Federal Government planned to make a special appropriation for the exposition, but to date we have had no word from Dr.

Woods. Also, the State of Illinois expected to appropriate money for the exposition, but has not yet done so. Until funds are available, no definite plans can be made.

The acting chairman has been somewhat remiss in that he has not had any extensive correspondence with those in charge of the various phases of the exposition. Before doing this, he has felt that some provision should be made by the Society to have a meeting of its committee in Chicago, where some ideas could be obtained at first hand as to the possibilities of a worth-while exhibit. At least those members close to Chicago could attend this meeting. It is quite difficult to visualize the plan of the exhibition from the general plans that are available at the present time.

H. W. ANDERSON, *Acting Chairman.*

Committee on Extension Program. A full day's extension program was originally planned for New Orleans. In the course of correspondence it was decided that discussion of successes and failures in projects would bring out all the essential details needed in putting across any projects, probably in a better way than to try to analyze the question and present the different phases of the question.

Among other things we wished to point out how the extension pathologist is constantly discovering new problems for research and how he must modify and change the discoveries of the research men before they became adaptable to farm conditions.

Owing to the inability of many extension pathologists to attend the meetings this year, this program was postponed until another year, and it was agreed to revive the EXTENSION PATHOLOGIST and to carry out our discussions in its pages.

CHAS. GREGORY, *Chairman.*

Auditing Committee. The accounts of The American Phytopathological Society and of PHYTOPATHOLOGY for the year past have been examined and the totals of accounts for receipts and expenditures, including vouchers, were found satisfactory and correct.

H. A. EDSON,
J. F. ADAMS.

Resolutions Committee. A committee consisting of E. C. Stakman, G. F. Weber, and H. W. Anderson, brought in the following report, which was adopted by the Society.

Resolved: That the members of The American Phytopathological Society extend their sincerest thanks to the members of the local committee on arrangements for their efficient efforts in contributing to the success of the New Orleans meeting.

Resolved: That the Society express its appreciation to Tulane University for the excellent facilities furnished for the meetings of the various sections of the Society.

Resolved: That the members of the Society extend their sincere thanks to Prof. C. W. Edgerton and his colleagues for the splendid entertainment furnished those in attendance at the New Orleans meeting.

Resolved: That The American Phytopathological Society express to President C. S. Clark of Southern University their appreciation of the splendid musical program furnished by the male quartet of his institution and their accompanist at the annual banquet of the Society.

ACTION OF THE COUNCIL

In addition to making the appointments mentioned in the first part of this report, the Council reported the following actions which were approved by the Society.

1. On consideration of an invitation to meet with the A. A. A. S. summer meeting, scheduled for Syracuse, N. Y., in late June, it is recommended that no summer meeting be held in 1932.

2. That, as was the case in 1930 and 1931, the editor of PHYTOPATHOLOGY be allowed actual expenses for 1932 up to or within $300.00 for secretarial and editorial assistance.

3. That the editor in chief be reimbursed by the Society for his travel expenses to the present meeting.

4. That the Business Manager of PHYTOPATHOLOGY, in order to make storage space for the growing supply of back numbers, be authorized to offer for sale during a limited period excess volumes of PHYTOPATHOLOGY down to a limit decided by him as safe, at a price of approximately $3.00 per volume plus postage.

MISCELLANEOUS BUSINESS

The reports of the various officers and committees as given in the preceding pages of this report were adopted by the Society.

The Secretary read a letter of November 9 from Dr. E. J. Butler, Director of the Imperial Mycological Institute, England, in which reference was made to the settee presented that institution by this Society. The following paragraph from the letter is quoted:

> "In conclusion may I ask you to express to the donors our great appreciation of this most graceful and generous mark of their interest in the work of the Imperial Mycological Institute which I hope will always and to an ever-increasing extent serve as one of the links that unites the phytopathologists of the two great English-speaking races."

FREDERICK JOHN PRITCHARD

DECEMBER 24, 1874–JANUARY 13, 1931

Frederick John Pritchard was graduated from the University of Nebraska in 1904 with the degree of Bachelor of Science. He pursued graduate study at Cornell University from 1907 to 1909 and at the University of Wisconsin from 1909 to 1910.

From 1904 to 1907 he was instructor and assistant professor in botany at the North Dakota Agricultural College and Experiment Station. From 1907 to 1909 he was assistant in plant breeding at Cornell University. From 1909 to 1910 he was assistant in botany at the University of Wisconsin. From 1910 to the time of his death, Mr. Pritchard was in the employ of the Bureau of Plant Industry, U. S. Department of Agriculture, advancing from agent and assistant physiologist to senior physiologist.

Mr. Pritchard was a persistent and painstaking worker in the field of practical plant breeding and will long be remembered for his development of several varieties of tomato, which were not only resistant to wilt and other diseases but of excellent quality. He was of a kindly disposition and possessed an unusual ability for making friends quickly. He was devoted to his home and family and spent all his spare time there.

LOUIS HERMANN PAMMEL

APRIL 19, 1862–MARCH 23, 1931

Louis Hermann Pammel was graduated from the University of Wisconsin in 1885 with the degree of Bachelor of Agriculture, and in 1889 he received the degree of Master of Science from the same institution. In 1899, he received the degree of Doctor of Philosophy from Washington University (St. Louis), and in 1925 he was honored by the University of Wisconsin with the degree of Doctor of Science.

From 1885 to 1886, Dr. Pammel was private assistant to Dr. W. G. Farlow at Harvard University; from 1886 to 1889, he was assistant in the Shaw School of Botany, Washington University (St. Louis); from 1889 to the time of his death, he was professor of botany at Iowa State College. He did special work for the Texas Agricultural Experiment Station and the Division of Vegetable Pathology, U. S. Department of Agriculture, in 1889; for the Division of Agrostology, U. S. Department of Agriculture, in 1897; for the Bureau of Forestry, U. S. Department of Agriculture, 1899–1902; and for the Bureau of Plant Industry, U. S. Department of Agriculture, in 1902.

He was a charter member of The American Phytopathological Society and a member of a number of botanical societies and academies of science.

Dr. Pammel was a man of unusually broad interests in the entire field of botany. He was a keen observer, untiring collector, ready writer, capable administrator, and inspiring teacher. He was a natural leader, always highly appreciative of the contributions of others. Certainly he strove always "to be of service to humanity."

WARNER JACKSON MORSE

OCTOBER 30, 1872–MARCH 25, 1931

Warner Jackson Morse was graduated from the Johnson (Vermont) Normal School in 1893. From the University of Vermont he received the earned degrees of Bachelor of Science in 1898 and Master of Science in 1903. The same institution bestowed upon him the honorary degree of Doctor of Science in 1923. He pursued his doctorate work at the University of Wisconsin, where he took his degree of Doctor of Philosophy in 1912.

From 1899 to 1901, he was teacher of natural sciences, Montpelier (Vermont) Seminary. At the University of Vermont he was instructor of botany, 1901–1905, and assistant professor in bacteriology, 1905–1906. He was also assistant botanist at the Vermont Agricultural Experiment Station from 1901 until 1906. At the Maine Agricultural Experiment Station he was head of the department of plant pathology from 1906 to June 30, 1923, and director from 1921 to the time of his death on March 25, 1931.

Dr. Morse was a highly capable and productive investigator, a loving husband and father, and a congenial and loyal friend. The known and tried made a much stronger appeal to him than the new and the untested. In keeping with his other sturdy qualities were his unvarying honesty and indiscriminating justness. He was a man of high ideals and at the same time was practical-minded. "To be of service" indeed characterized his every activity, and friendliness and considerateness his every personal relation.

CALVIN HENRY KAUFFMAN

MARCH 1, 1869–JUNE 14, 1931

Calvin Henry Kauffman was graduated from Harvard University in 1895 with the degree of Bachelor of Arts. He spent one year (1901–1902) in graduate study at the University of Wisconsin and two years (1902–1904) at Cornell University. He then continued his studies at the University of Michigan, where he received the degree of Doctor of Philosophy in 1907.

From 1887 to 1890 he taught in the secondary schools of Lebanon, Pennsylvania, and from 1896 to 1898 was principal there. From 1898 to 1900 he taught in a high school at Decatur, Indiana, and the following year in a normal school at Bushnell, Illinois. In 1904 he was appointed to an instructorship in the department of botany of the University of Michigan, where he spent the rest of his life. He became an assistant professor in 1912, associate professor in 1920, and professor in 1931. He also was appointed director of the University Herbarium in 1921. From 1917 to 1919 he was on leave from the University of Michigan, serving as pathological inspector on the Federal Horticultural Board.

Doctor Kauffman was an inspiring teacher and a tireless, enthusiastic investigator. By his thorough and critical studies mycology has been greatly enriched.

VI INTERNATIONAL BOTANICAL CONGRESS

According to a decision by the V International Botanical Congress at Cambridge in 1930, the Sixth Congress will be held in Holland in 1935. An Executive Committee has been formed, President of which is Professor Dr. F. A. F. C. Went (Utrecht), while Professor Dr. J. C. Schoute (Groningen) will act as Vice-President, Dr. W. C. de Leeuw (Bilthoven) as Treasurer and Dr. M. J. Sirks (Wageningen) as Secretary. The Committee has decided that the VI Congress will meet at Amsterdam, September 9th–14th, 1935. Scientific Societies are kindly requested to reckon with these data in planning their own meetings.

VI INTERNATIONALER BOTANISCHER KONGRESS

Laut Beschluss des V. Internationaler Botanischen Kongresses in Cambridge, 1930, wird der Sechste Kongress 1935 in Holland abgehalten werden. Für diesen Kongress hat sich ein Vorbereitungsausschuss gebildet unter der Führung der Herren Prof. Dr. F. A. F. C. Went (Utrecht) Vorsitzender, Prof. Dr. J. C. Schoute (Groningen) Stellvertr. Vorsitzender, Dr. W. C. deLeeuw (Bilthoven) Schatzmeister und Dr. M. J. Sirks (Wageningen) Schrifführer. Der VI Kongress wird vom 9 bis 14 September 1935 in Amsterdam tagen. Wissenschaftliche Gesellschaften wedern freundlichst gebeten, diese Daten bei dr Festellung ihrer Sitzungen berücksichtigen zu wollen.

VI CONGRÉS INTERNATIONAL DE BOTANIQUE

Le V Congrès International de Botanique à Cambridge 1930 a décidé que le Sixième Congrès aura lieu en 1935 en Hollande. Un Comité d'Organisation a été établi sous la direction de MM. le Professeur Dr. F. A. F. C. Went (Utrecht) Président, le Professeur Dr. J. C. Schoute (Groningen) Vice-Président, le Dr. W. C. de Leeuw (Bilthoven) Trésorier et le Dr. M. J. Sirks (Wageningen) Secrétaire. Le VI Congrès se réunira à Amsterdam du 9 au 14 septembre 1935. Les Sociétés scientifiques sont priéss de bien vouloir tenir compte de ces dates en fixant celles d'autres réunions scientifiques.